INTEGRATED EDITION OF THE PETROLEUM ENGINEER

PETROLEUM Engineer for MANAGEMENT

MAY 1961

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ONE DOLLAR PER COPY

INDUSTRY BUCKS RECESSION TREND

Crude oil and oil products sales almost unchanged in 1960 . . . Petrochemicals, natural gas, and cost reduction pull company earnings up 9%.

14th Annual Report Survey

LOOK AT THE TURBULENCE in casing or tubing during a well stimulation treatment. Until recently, much of the available pumping horsepower was spent just to overcome this turbulence.

TURBULENCE IS SUPPRESSED when Slick Water or Slick Oil is added to the treating fluid. Injection rates may be more than doubled or required horsepower may be cut by as much as 70 per cent.

how Dowell's new friction-reducing agents help increase profits from fracturing and acidizing

These cross-section illustrations, as visualized by an engineer, show fluid flow down casing or tubing during fracturing or acidizing. They show how extreme turbulence wastes pump horsepower; much of the available horsepower must be used to fight this turbulence.

Slick Water* and Slick Oil* – the Dowell-developed friction-reducing agents for water, acid and oil – have made it possible to more than double the injection rate with the same horsepower. In other cases, a given injection rate has been achieved with only one pump instead of three. In still other cases, these agents have saved the cost of pulling tubing. High-injection-rate treatments have been performed down strings of 2⅞-inch casing in multiple tubingless completions. Slick Water and Slick Oil have made large fracturing treatments economical for some marginal wells by permitting the use of lower-cost fluids. They have helped many operators get exceptional production increases per dollar invested.

Ask your Dowell representative how these new friction-reducing agents can help you increase profits from well stimulation. Dowell services and products are offered from more than 150 offices and stations in the United States, Canada, Venezuela, Argentina, Germany, France and the Sahara area. Dowell, Tulsa 1, Oklahoma.

*DOWELL TRADEMARK

SERVICES FOR THE OIL INDUSTRY **DOWELL** DIVISION OF THE DOW CHEMICAL COMPANY

PETROLEUM Engineer for MANAGEMENT

NUMBER 5 • VOLUME 33 • MAY, 1961

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Annual coverage of oil and gas operations in more than 100 countries and territories coming in June issue. This review of what happened in 1960 gives you supplemental information for your Global Notebook.

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highlights *and footnotes of the news*

Demand dropped 10% in March under last year due principally to weather conditions, Chase Manhattan Bank reported. It also stated that liquid petroleum demand averaged 2% in first quarter below last year. IPAA's estimate is that first quarter petroleum demand was down 1% and warned that reduced refinery runs should be cut.

Societe Italo Tunisienne d'Exploitation Petroliere has been formed under an agreement calling for automatic 50% Tunisian Government participation in the event oil is found, and permitting the Government to receive up to 75% of profits. Bids are to be given for construction of refinery.

"President Kennedy's suggestions for reorganizing the FPC do not appear to offer any real help to the natural gas consumer or the gas producers," announced Estill S. Heyser, Jr., president of Texas Mid-Continent Oil and Gas Association. "No matter how many commissioners are assigned to the Commission, they will not be able to regulate effectively under the present natural gas act. The proposal to exempt all the producers who sell less than two billion cubic feet of gas a year is, in itself, an admission that the law cannot be applied."

Gulf Oil Company received another award from Uruguay Government for 5,910,000 bbl of Kuwait crude, thus sweeping all contracts to fill 1961-63 crude oil needs of the Government fuel monopoly, except for one award to YPF of Argentina.

Otto Dewey Donnell, 77, retired president of Ohio Oil Company, civic leader and philanthropist, died April 9. He had been retired from the company since 1948 after over 40 years' service. In 1895, Mr. Donnell began his career with Ohio Oil as an office boy during school vacations. He received a degree in mechanical engineering from Case Institute of Technology in 1906. He was elected president in 1927, succeeding his late father, J. C. Donnell. In 1953, API honored Mr. Donnell with its "Gold Medal for Distinguished Achievement."

British Petroleum increased net sales by 7.7% in 1960; was down 3% in earnings but moved dividends up slightly. Profit margins narrowed from 10.3% on sales in 1959 to 9.3% in 1960. (See page A-26 for reports of U.S. companies.)

Natural gas experts of U. S. and Russia hope to exchange visits under plans being mapped by the U. S. State Department and the Soviet, the American Gas Association announced. The Soviet group would visit the U. S. in May and the American delegation would tour Russia in July.

The Saudi Government has been sanctioned by the Council of Ministers to purchase the equivalent of $7 million in shares in the Japanese-owned Arabian Oil Company.

Continental Oil filed with the Securities and Exchange Commission a registration statement relating to a proposed offering of $100,000,000 debentures, due in 1991. Proceeds from the sale would be used to retire bank debt and for projected capital expenditures and investments in and advances to affiliates.

U. S. Navy will accept bids for 6.2 million bbl of special fuel oil, a half-year's requirements along the eastern seaboard, in exchange for surplus farm products. For the barter program, Navy would contract with a U. S. company to supply a certain amount of foreign origin oil in exchange for government-owned surplus farm goods.

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The Mile and a Half That Covers the World

There's quite a story behind the simple address plate that brought you this month's copy of The Engineer. Because proper handling of some 50,000 plates every month is part of our job, we hadn't stopped to think much about it until a recent visitor asked about the mechanics.

It really begins long before your subscription order reaches our office.

If you are a typical subscriber, you ordered a personal subscription as the result of an offer you received in the mail. You have to be an important person to even get one of these invitations! Last year we checked more than 100,000 oil industry personnel names to uncover 14,500 qualified prospects we could add to our mail promotion list.

Perhaps you moved in the meantime. So, our prospect card had to be corrected . . . a second or even third invitation mailed before you accepted.

Then the big day! Your order arrived in the morning's mail. (Checking the daily mail is a liberal education in "what's happening, where," throughout the petroleum world. On a recent typical day, we received more than a hundred subscription orders . . . from a Trans-Canada Pipelines foreman in Saskatchewan . . . a project engineer constructing Oasis Oil Company's new Libya line . . . a drilling contractor making hole near Mt. Pleasant, Michigan . . . a PETROBRAS supervisor in Rio.)

Even though we had pre-qualified your position, we still had to make sure we had your full name, address, company . . . correct title and division of the industry. Your payment had to be recorded and balanced with the day's receipts.

To properly serve you, our editors need up-to-date information about your responsibilities and interests. And, as a member of the Audit Bureau of Circulations, we must be able to substantiate your position and payment throughout the life of your subscription. Each year, ABC auditors verify our circulation records . . . as carefully as any bank examiner. This audit protects advertisers who make it possible for qualified readers to enjoy a subscription for a fraction of the actual publishing cost.

More than 18 separate steps are taken to process your order. We check for any previous order, remove your name from our promotion list, cut and proof your address plate. Your name goes in three files . . . by company, alphabetically, and the geographical plate file.

Our "plate file" requires 1500 changes of address every month, since oil and gas men work in the most mobile of all industries. To serve subscribers throughout the United States and 78 free-world countries, we address a mile and a half of plates . . . print a stack of magazines higher than the Empire State Building . . . 13 times a year.

In our opinion (and we have the names and verified titles to prove it) that "mile and a half" of subscribers' plates is the life-blood of the world-wide petroleum industry. Each one is for an individual we are pleased and honored to serve. The one thing that can't be measured is the effort to which we would go to serve you.

Joe B. Hoode

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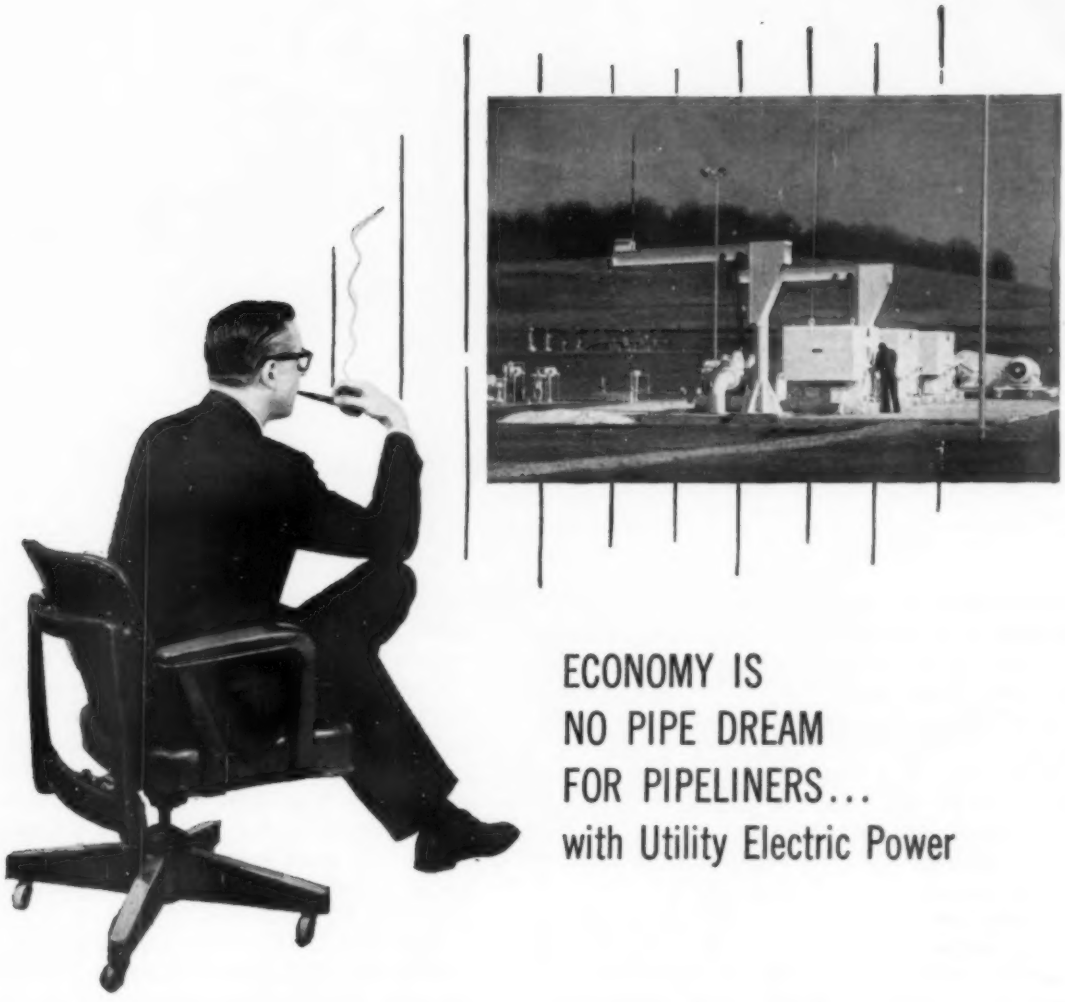

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Course of Oil

capital diet too thin

EVERY COUNTRY in the world needs capital—needs it as surely as a human being needs food to live. That's the essence of the life-giving Marshall plan, of pleas from undeveloped countries for more funds, of perpetual hoarding by the Soviet State through tight restrictions on individual consumption.

Capital may be a handful of seed, hidden from famished people that there may be another harvest, a greater abundance. It may be a multi-million-dollar refinery so man's energy can be multiplied over and over that there may be a brighter tomorrow.

Wherever you find it, capital is the good bread of progress. Without it life flattens and deteriorates and retrogrades. Starvation sets in and weakness spreads.

Most of our economic trouble today comes from a long drawn-out restricted diet of capital in the United States. There is only one way to generate capital—from savings or profits over and above the costs of operations. Since World War II our capital has been syphoned off—about $90 billion has gone abroad to people we decided needed capital worse than we did. Each year government takes one-third of our capital in taxes that might be used for growth. Practically speaking, taxes are capital funds used rather than invested.

Last month, the Federal Government agreed to appropriate one billion tax dollars for unemployment payments. Here is capital seed that could have grown more than 500,000 new jobs. Instead, we eat it now. This is only the latest example of determined and persistent malnutrition of our economic body, forced to work on less than its capital needs for a generation.

Look at the table from financial reports in this issue that shows the taxes per company share compared to income and dividends. For integrated companies, a media is a $2.00 dividend to investors, $14 in taxes to governments. The $2.00 dividend may still be clipped by government after it's paid to the shareholder. Producers have much less taxes but don't forget they are actually selling their capital when they sell their oil and gas reserves.

Another tax that takes capital comes from low depreciation and depletion standards. To replace original plant and equipment and reserves may take two to ten times the sum allowed by tax regulations. So capital that should go to expansion must be used to replace obsolete equipment and depleted oil and gas fields. Is it any wonder our growth has been stunted?

It takes an average of about $19,000 to capitalize one job but the margin of profit left in the hands of business and industry grows less as the people who want jobs increase. Capital is snatched away for unproductive chores and our economy loses more vigor.

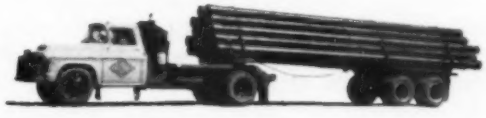
The Administration quickly recognizes the need for capital in Bolivia and Nigeria and Indonesia. When will our statesmen recognize the desperate need of capital in the United States?

Ernestine Adams

Congrats and $25 to Peter Fernandez, Texaco T'Dad Inc. 18 Concord Road, Pointe-a-Pierre Trinidad, W.I.

Joe Roughneck is apt to set up a howl, too, if asked to handle steel pipe that is less than superior.

More and more experienced oil and gas men have switched to Lone Star API casing, tubing and line pipe, because it's "tough, top quality and delivered fast." Your best guarantee of rugged API standards is Lone Star's uncompromising quality control.



Neighbor, wherever you are, specify Lone Star and we both get a good deal.

Lone Star STEEL COMPANY

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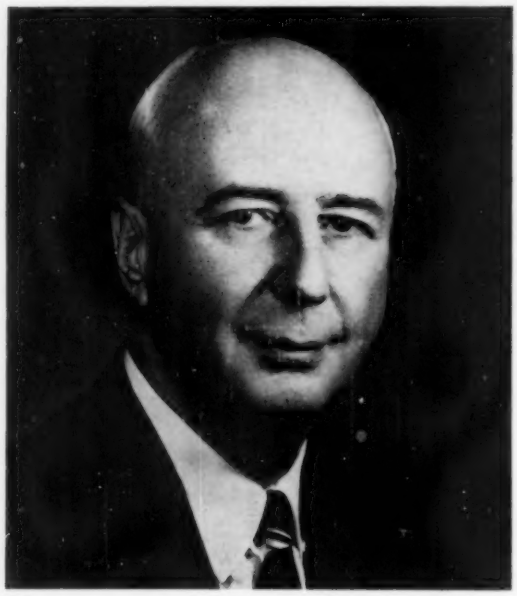
petroleum profile

ROBERT L. MILLIGAN, the president of The Pure Oil Company, is not a man to do things halfway.

A few years ago on a business trip to South America he was deeply impressed by the beauty of a dressing table in a Brazilian home. He had been considering taking up woodworking as a hobby, and the Brazilian piece decided him. Upon his return to the United States, he showed a furniture-designer friend some photographs he had taken of the table. The friend volunteered to make working drawings from the photographs. Once the drawings were completed, Mr. Milligan studied and read up on his subject and bought the necessary tools.

The dressing table was a project to challenge the skill of men with years of woodworking experience, but "Bill"



ROBERT L. MILLIGAN
President
The Pure Oil Company

Milligan, with careful analysis and preparation, quietly went to work. With hardly an error he turned out a lovely rock maple dressing table that would have been a credit to an expert.

Since 1954 when he became Pure's president, he has made the same direct approach to the company's problems.

He is a man of energy and ambition. His ambition is associated with the progress that the company has made during his tenure as president. In the last seven years, Pure has successfully extended its search for oil beyond the United States into South America and is exploring in Spanish Sahara, and examining the possibility of branching out into the Middle East. The company has acquired a large refinery in the Chicago area, has added extensively to its marketing facilities, including building up the nation's largest chain of truck stops, and added over four thousand miles to its pipeline network. Each year operations have become more efficient.

In a talk last year before the Chicago Sunday Evening Club, his philosophy showed through. He said:

"I have long had the conviction that I should strive to be constructive and objective in the sense of acting rather than being subjective — being acted upon — to be positive rather than negative in attitude.

"I believe in respecting the dignity and individuality of all others — in having consideration and tolerance and in making allowance for failures in communication.

"In order to do well in a corporation of size — I believe one must adopt a corporate philosophy. One must be anxious and willing to work cheerfully and in a friendly manner with others in true teamwork. He should demonstrate a sincere desire to exercise powers of persuasion and influence rather than of direction by giving orders."

Mr. Milligan has these powers of persuasion and he backs them up with a remarkable fund of knowledge about all aspects of the company's operations. This knowledge is the prelude of decisions and action.

Born in Springfield, Ohio, on October 11, 1900, "Bill" Milligan received his public school education there. At 18 he enlisted in the Marines, but his military career was cut short by the Armistice after a month. When he attended Ohio Wesleyan University, he managed the "annual" and the football team.

Returning to Springfield after graduation, he went to work with the Fairbanks Company, manufacturer of the metal framework or "plates" for pianos. He became superintendent and later vice president and general manager.

In 1929 Mr. Milligan joined Pure Oil's treasury department. In 1933 he became assistant secretary-assistant treasurer. He was elected treasurer in 1947, vice president and treasurer in 1949, executive vice president in 1951 and president in 1954. He has been a director since 1953 and last year he succeeded Rawleigh Warner, chairman of the board, as the company's chief executive officer.

He is a director of the Continental Illinois National Bank and Trust Company of Chicago, Montgomery Ward and Company, American Steel Foundries, the National Industrial Conference Board, and the American Petroleum Institute. In addition, he is a trustee of Illinois Institute of Technology and Ohio Wesleyan University, and a member of Northwestern University Associates and the National Petroleum Council. In Chicago Mr. Milligan has been a leader in numerous community drives. He served as a member of the Evanston Board of Education from 1943 to 1951, and more recently as a trustee of the First Presbyterian Church of Evanston.

Besides woodworking, Mr. Milligan enjoys photography, hunting, fishing, and golf, and excels at all except golf.

He and his wife, the former Alice Connell of Findlay, Ohio, live in Evanston. They have three sons: Warren, who lives in Cleveland and works for the Glidden Company, Robert of Evanston, an employee of International Business Machines, and David, a college student. There are four grandchildren.

A 60-INCH VIEW OF CAT'S POWER SHIFT 583 PIPELAYERS

Report from Jack Hodges, General Supt., J. P. Neill & Company, Inc., Birmingham, Alabama

"The power shift on the new Cat 583 allows split-second shifts when juggling 60" pipe. The operator can handle the draw works levers and change travel speeds by nudging the *single* transmission lever with his forearm—impossible otherwise. When climbing these grades, he can smoothly drop to a lower gear to keep the load moving. Machines with other type transmissions must stop and slow down the operation."

Jack Hodges is talking about performance from the two 583s working on the industrial water line from Fort Smith Dam to Birmingham, Ala. They're handling 60" pipe, weighing 20,000 lb. per 40' joint, over rough terrain with grades up to 67½ degrees. "It's the kind of job that brings out the best and shows up the worst in any machine. That's why the 583s look so good."

The beautifully engineered combination of 235 HP, 137,000 LB. LIFT CAPACITY, POWER SHIFT TRANSMISSION, and an unmatched 21" GROUND CLEARANCE equip the 583 for heavy work in mountains or swamps . . . work that other machines can't handle over ground where other machines can't go. No wonder men who work with the 583 talk long and favorably about it.

For your own record-setting production *with low cost* . . . see your Caterpillar Dealer.

Caterpillar Tractor Co., General Offices, Peoria, Ill., U.S.A.

CATERPILLAR

Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

HEAVY-DUTY PIPELAYERS FOR THE HARD WORK

the conference table

Talk Over $71 Million LPG Line

Robert E. Thomas (left above), president of Mid-America Pipeline, visits with Minnesota Governor Elmer L. Andersen following a luncheon in St. Paul saluting Mid-America for bringing its 2200-mile pipeline from Texas to the Pine Bend terminal, south of the Twin Cities. Civic and industrial leaders heard Thomas predict that the pipeline will become a force for stimulating new industry in Minnesota.

To be alive at all involves some risk. — Harold Macmillan.

Penny Saved Is 14 Earned

In the Eastern Division News of Tidewater Oil Company is an arresting editorial called "Penny Saved Is 14 Earned". The editor, Joseph Schleyer, points out that based on the average return on total sales, it would be necessary for Tidewater to make additional sales of almost $14,000 to produce a profit increase equal to a cost reduction of $1,000.

Under today's business conditions, he says, with paper-thin profit margins and high taxes, a penny saved through efficiency and intelligent cost-cutting means much more than a penny earned through increased sales.

For Tidewater and for a great many oil companies, a penny saved means as much as 14 earned.

More on Australia

Our author for the Australia Global Notebook published in April sent us more statistics which you may be interested in adding to those on page E-11. J. M. Rayner wrote that in 1960:

Imports of crude were 232,125 b/d;
Imports of products, 26,712 b/d;
Product consumption, 228,502 b/d (including refinery fuel);
Exports of products were 31,760 b/d.

Prosperity Has to Have a Pattern

Last month our "Course of Oil" editorial was a request for old or new ideas on how economic progress could be made in a private enterprise system. In a Communist system, initiative rests with the ruling clique of the national system. But with hundreds of thousands of individual enterprisers how do you tackle a recession, for instance? Must a private Capitalist system also leave economic patterns to our government planners?

We sent a copy of the editorial to a score of industry leaders and we publish here some excellent answers:

In an enthusiastic, affirmative statement for our achievements, W. C. Norman, head of Colorado Oil and Gas Corporation, writes:

I believe management already provides the pattern for prosperity and that we are destined for even greater advances through business leadership.

American businessmen — especially those in the oil and gas industry — are devoting all their energy, investing capital, and taking risks for the sole purpose of building a profitable and prosperous future.

There are some who try to belittle the profit motive as the mainspring of business. But look at its results. The profit motive needs no defense. It is a vital, positive force that brings a prosperous life of material benefits like good food, good housing, leisure time, medical care and education for our families. What's wrong with that? As a recent visitor from a communist country said: "What a delight to be in the United States where things are produced and sold with such a nice clean motive as making a profit."

Businessmen through the stormiest ages have promoted progress by investing in and developing enterprises that have improved living conditions, broadened individual freedom and contributed to the general welfare.

They have done this by generating and diffusing wealth. A recently published volume, *Life Without Fear* by T. V. Smith, makes an interesting point: "Capitalism is mankind's most creative invention; it creates goods, in surplus; it creates and distributes purchasing power to absorb the goods so plentifully produced; it creates an atmosphere in which men can enjoy not only their own products but, most of all, can enjoy their betters, without disdaining their inferiors. Capitalism is the creative way of life."

The oil and gas industry is the best example of dynamic capitalism at work. No other business rivals the oil leader in his thrusts into new frontiers, whether it be miles deep into the sea, into the steaming jungles of South America, into the burning sands of North Africa or into the frozen wastes of Alaska.

Exploring, risking and investing — this is leadership in its truest sense. That is the kind of leadership that produces wealth and prosperity which in turn provide the good life. That is what all human beings strive for and business leaders, more than any other class, afford the means for that satisfaction.

The business leader can best contribute to a prosperous future by building his own company into a strong, profit-making organization. Successful businesses mean a strong United States that can fulfill its obligations to its own citizens and contribute to expanding the good life to less fortunate people around the world.

End of Mr. Norman's statement.

For Atlantic Refining Company, Leslie A. Webb took this realistic view:

Whether management will be able to provide the necessary leadership for economic growth is among the most vital questions facing us today. The way in which it is answered will have a profound effect on our future.

Management of private enterprise has amply proven itself

Good Wells Make Good News

Outstanding Results from Recent Dowell Fracturing Treatments

May, 1961

Dowell uses both new and time-proven material and techniques to help operators improve wells. Here are four recent examples:

- **Taylor County, West Texas** (New Oil Well) This development well was to be completed in the Shep Gray Sand Pool at 5321 feet. Operator wanted to get maximum initial production. Dowell notched the formation with Abrasijet* abrasive jetting service, then fractured. A two-jet gun was rotated at 1¼ rpm during jetting to notch casing. Following a 10-gallon spearhead of Freflo* surfactant, Petrojel* fracturing service was used. 11,760 gallons gelled crude, modified with fluid loss control agent, were used to carry 3400 pounds 20-40 mesh sand and 700 pounds 8-12 mesh walnut shells. Well tested 168 bopd in a field where the average test is about 70 bopd.

- **Crook County, Wyoming** (Old Oil Well) This well, completed in 1959, had originally produced 168 bopd, but production had declined to 50 bopd. Pay was the Dakota at about 6000 feet. Dowell fractured using Petrojel. A 200-gallon spearhead of Mud Acid was followed by 20,000 gallons gelled lease crude with fluid loss additive and 20,000 pounds sand. Injection was 22 bpm at 2300 psi. 40 days after treatment, production was 960 bopd with no water.

- **Ouachita County, Arkansas** (Old Oil Well) Production from this well in the Blossom sand, from 2110 to 2117 feet, had declined to 3 bopd. Dowell treated using Riverfrac*. 40,000 gallons salt water with demulsifier added, 20,000 pounds 20-40 mesh sand and 20,000 pounds 10-20 mesh sand were injected down 2½-inch tubing at 14 bpm and 1900 psi. After treatment, production was 33 bopd.

- **Hemphill County, Texas Panhandle** (New Gas Well) An interval in the upper Morrow was perforated from 11,930 to 11,950 feet. It gave no show on natural swab test. Well was fractured down 2⅜-inch tubing twice using Waterfrac. For the first treatment, 20,000 gallons gelled water and 17,750 pounds sand were injected at 10.5 bpm. After load returned, well tested 8500 mcfd with five barrels distillate per million. The second treatment consisted of 2000 gallons regular acid, 50,000 gallons gelled water and 50,000 pounds sand injected at 14.5 bpm. Twenty-four hour shut-in pressure was 5500 psi and well tested 9000 mcfd with 20 barrels distillate per million -- 180 barrels of distillate per day!

Ask your Dowell representative for suggestions about how to get better production from your wells. Dowell services and products are offered from more than 150 offices and stations in the United States, Canada, Venezuela, Argentina, Germany, France and the Sahara area. Dowell, Tulsa 1, Oklahoma.

*DOWELL TRADEMARK

Services for the oil industry DOWELL
DIVISION OF THE DOW CHEMICAL COMPANY

by providing the leadership for this country's unrivalled economic progress. The world has yet to offer *any* standard by which our performance could be judged deficient. Only our own ideals, borne of confidence in our demonstrated capability for continuing progress, suggest still higher standards of performance.

The question that remains is not whether management can provide the necessary leadership, but whether its leadership will continue to be accepted. Affluence has brought problems of its own, and the issue is likely to be decided by how realistically we deal with such problems.

Foremost among these is the fact that our growth does not follow an even course. The recurrent periods of sub-standard performance cannot be taken lightly. But this periodic tendency to outrun our needs must be viewed realistically as a problem associated with relative abundance. We must be careful that we do not eliminate these occasional periods of sub-standard performance by the expedient of lowering our standards.

Certainly there is no room for complacency. But impatience in attaining our goals for improvement can be equally dangerous if it is translated into dissatisfaction with the very system that has made those goals appear realistic.

L. F. McCollum, Continental Oil Company president, makes these forthright and specific comments:

You are quite right in that looking to Washington becomes habit-forming. This appears to be an easy way which doesn't always turn out to be right. Business and industry must regain initiative if we are to preserve the economic freedom that we now enjoy and if we are to cause the economy to grow. There is much work for many strong businessmen.

There are encouraging signs. To name a few: The interest demonstrated (both financial and physical effort) in the past election; industry investment in all types of research; an increased number of executives are presenting their views to Washington on many major issues including depletion allowance, use of highway funds, labor legislation, and what the government's role should be in the affairs of the nation.

Many companies regularly support institutes of higher learning with both money and manpower. There are a number of Conoco executives serving on university advisory boards or committees. We have several educators on an annual retainer basis and employ a number for summer work in various departments of our company. Our annual Financial Aid-to-Education Budget is well into the six figures and this is used for scholarships, fellowships, and direct grants.

We are aggressively expanding both at home and abroad. This phase of our business has caused rapid development of many young executives and broadened older ones. We have placed many retired managers in key positions to assist in the assimilation and growth of these new ventures.

I am proud Conoco can be classified as a builder. We are not waiting on the "Great White Father" to lead us to prosperity. We don't think the answer to industrial growth or the growth of our great country lies with government intervention in the system.

Referring to our suggestion for Senior Achievement projects sponsored by individual companies as Junior Achievement firms were, one reply stated:

In general, we are in agreement with your analysis of the problem—it is true that most economic remedies for the effects of the business cycle are political palliatives and not remedies; and usually end up with more taxes and more spending.

We are not, however, entirely in agreement as to how American business and business men are to go about creating a counterforce to the cycle independently of government. That some action should be taken in this area is undoubtedly true, but we do feel that such action should be collective rather than individual.

However, I think the subject has started some thinking and may still be productive of more specific reactions.

We appreciate the thoughtful, clearheaded approach, in these replies. We tend to overlook the leadership of business in community affairs that makes life more abundant. We accept matter-of-factly the funds and effort from business used to brace-up American education. We have been so engrossed in problems of progress, we have neglected problems of affluence.

There are more replies and most of the writers accept the premise that business and industry can act positively in economic revival—either collectively or as individual companies. We need more methods. Concentration of political power grows always at the expense of authority in economic enterprise. It is possible to offset the magnetism of political solutions to economic problems?

Irritated by Gasoline Prices

In a Public Opinion Poll in January released by Gallup Poll, gasoline was among the top three named as irritants to buyers because of high prices. After food bills and medical bills, gasoline ranked third. Percentage of buyers checking gasoline moved up from 5% in July, 1959 to 6% in January, 1961. Question put was: "Of all the things you buy or the services you pay for, which irritates you most because of high prices?"

Social Security No Bargain

Do you realize that a young man of 20 could buy from private insurance companies a life annuity yielding almost double the monthly Social Security benefits after he reaches 65? These include the employers contributions also, which in effect are paid as part of a man's wages.

This, then, is the annuity we call Social Security. As always with the government bureaucracy running it, the system costs twice as much as it would in private hands.

A man is known by the silence he keeps.—Oliver Herford

Profits Mean Progress

The Course of Oil (on taxes) fits into a speech made by an American Telephone and Telegraph executive to American Gas Association.

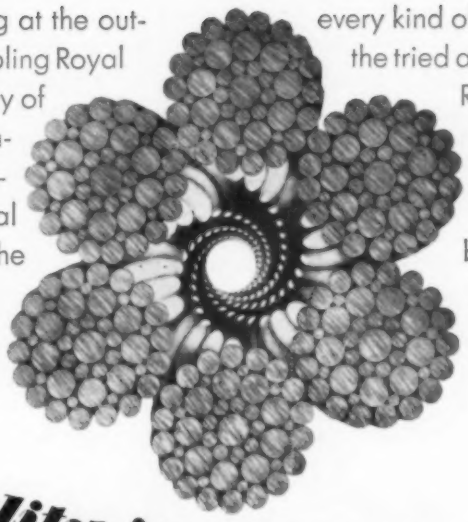
"When profit is poor," Carl Ulffers declared, "Employment is unstable. Expansions, if any, are of the shoe-string variety. Closed plants foster economic waste. Firms fail. Research is conspicuously absent. As a result of all this, nobody benefits. People lose jobs and the consumer gets less for his dollar."

In 1960, wages and salaries increased by 5%. Productivity increased by 2.5%. The margin between the products of our labor and the payment for the same labor is growing wider and wider.

It Isn't Only the Money, It's the Method

Pan American Petroleum Corporation (Standard Indiana company) paid $37 million in 1960 taxes to federal, state and local government. In order to do so, the firms accountants filed 2500 tax returns. Somehow that sounds worse than the money involved. One tax return puts a blight on April for us.

Here are two ways of looking at the outside and *inside* quality of Roebling Royal Blue Wire Rope—the uniformity of wires and strands. Their symmetry would be relatively insignificant, however, without Royal Blue's *extra* high strength. It's the combination that is the source of real wire rope savings. For long, economical service on every kind of job, there is no substitute for the tried and proven quality of Roebling Royal Blue. It pays off for *you*. Learn more about Royal Blue from your wire rope distributor, or write now for free booklet to Roebling's Wire Rope Division, Trenton 2, N.J.



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Branch Offices in Principal Cities
John A. Roebling's Sons Division
The Colorado Fuel and Iron Corporation.

Quality inside and outside

We put a lot of work into it—
You get a lot of work out of it

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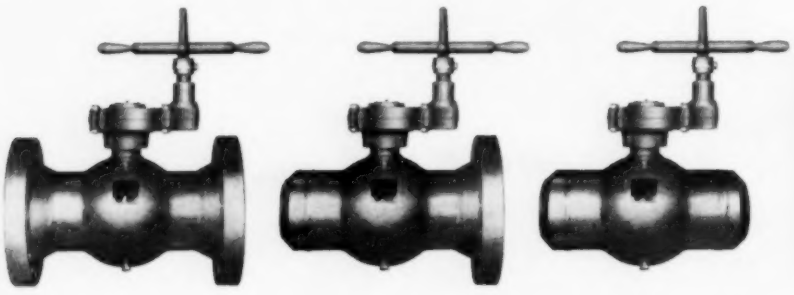
CAMERON BALL VALVES, developed by Cameron's continuing research and manufactured from steel and forgings produced by Cameron, assure you complete operating security. Engineered for general industrial use, Cameron Ball Valves are unexcelled for pipelines, refineries, chemical plants and oilfield service. They are available in sizes 2″ to 36″ in ASA and API pressure ratings and with any type end preparation desired.

NON-LUBRICATED, bonnetless and glandless Cameron Ball Valves are maintenance free. Amazingly compact and easy to operate, they are readily adaptable to remote or automated operation. The Cameron exclusive rotating seat feature incorporated in these valves has so extended valve life that the "sealed for life" construction is now practical for the first time. No other valve can give you as complete security with maximum economy.



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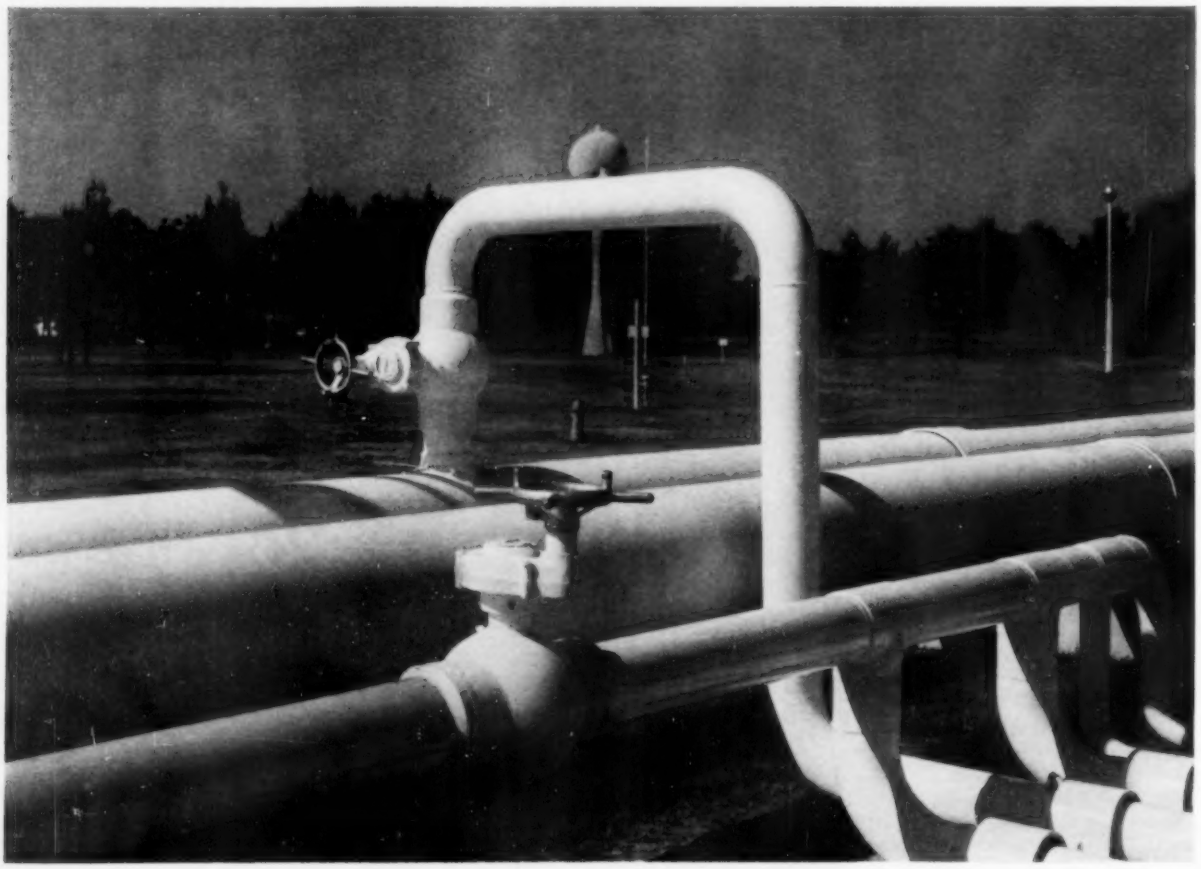
COMPLETE OPERATING SECURITY



SAVE SPACE, SAVE WEIGHT, SAVE MONEY!

Dyna V

There's a *difference*, as you can see! The 10-groove D-section sheave in the foreground is replaced with the narrow 8-groove 5-V Dyna-V sheave on the line shaft. *Same power*, in a far more compact installation, with a $477 difference in price. And big future savings in belt replacement costs!

Everyone is going Dyna-V! Thousands of installations reveal that Dyna-V performance is *even better* than promised when we first introduced this new compact drive. In medium and high horsepower ranges, savings go as high as 30%!

Dyna-V can handle 3 times as much power in the same space. Dyna-V Sheaves decrease shaft overhang, increase bearing life. And Dyna-V Belts possess *all* premium qualities. Conditions requiring static conductivity or resistance to oil, moisture and heat are met by Dyna-V's one grade—the finest. Ask your Dodge Distributor, or write us for complete drive bulletin. Dyna-V Drives are available for capacities from 1 to 1500 hp.

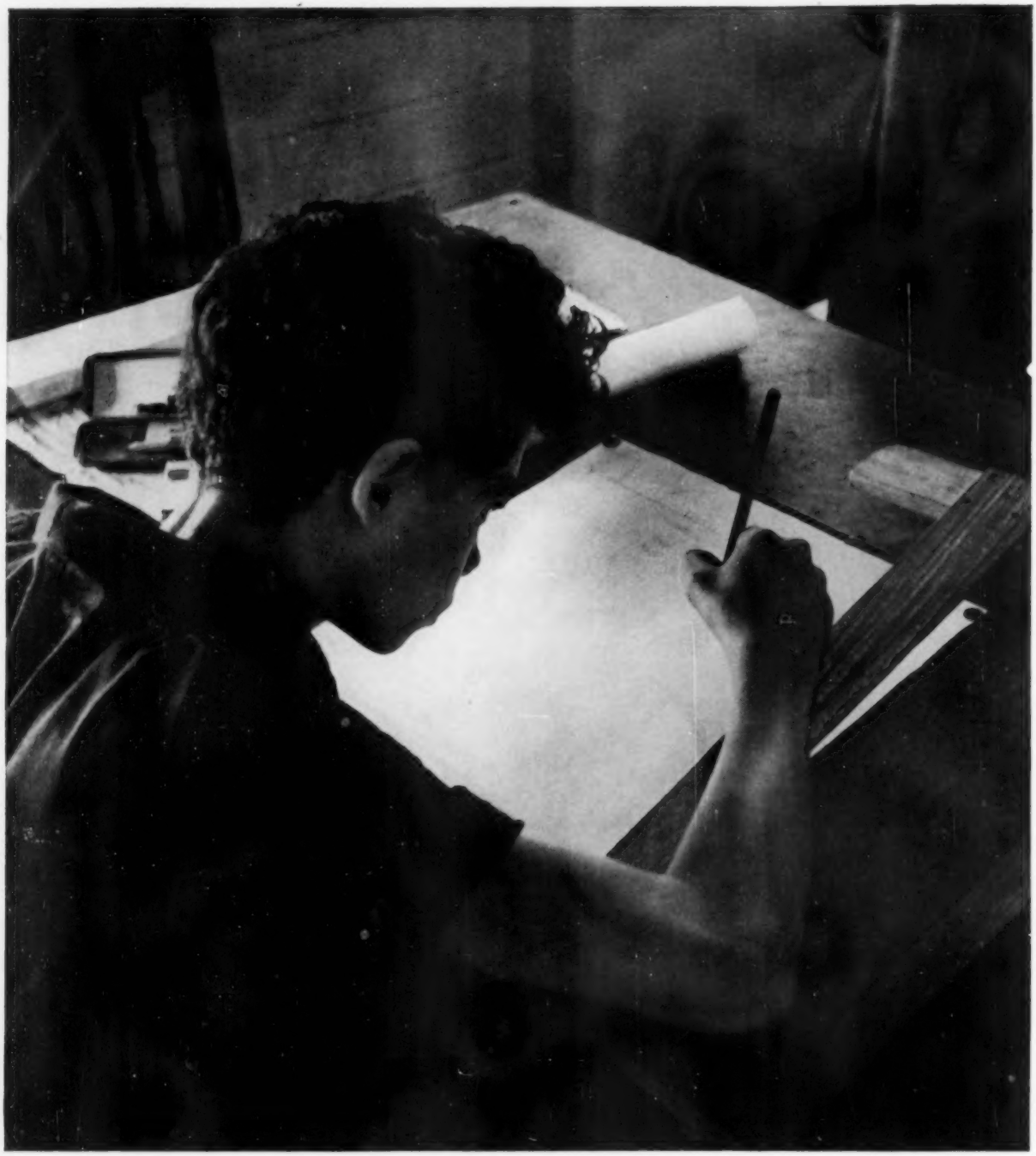
Dodge Manufacturing Corporation, 7900 Union St., Mishawaka, Ind.

The Products with the Pluses...

DODGE

of Mishawaka, Ind.

CALL THE TRANSMISSIONEER, your local Dodge Distributor. Look under "Dodge Transmissioneer" in the *white* pages of your phone book. Factory trained by Dodge, he can give you valuable assistance.



Texaco in Trinidad is a big investment in the development of oil—and individuals. A visitor to this lovely, lively island will see thousands of Trinidadians at work where once such opportunity did not exist. He will see boys, 16 to 20, enrolled in Texaco training courses, continuing as on-the-job-with-pay apprentices. Students showing unusual aptitudes are awarded Texaco scholarships for university study. For all, it is a dream of success and security come true. Texaco in Trinidad is creating new futures for the people, sound growth for the economy of the island.

TEXACO: SYMBOL OF WORLD-WIDE PROGRESS THROUGH PETROLEUM

Special Report to Users of Caterpillar Equipment: Custom TRACK SERVICE

Custom Track Service saves coal stripper $3298 by adding 3800 hours to track life

A coal stripper, ripping and 'dozing rocky overburden 7 days a week around the clock, was averaging 2300 hours of life before he *replaced* most of his totally destroyed track group parts. At the suggestion of his Cat Dealer, the stripper tried new, larger-size undercarriage parts. By following recommendations of the dealer's undercarriage specialist at 2440 and 4030 hours, the undercarriage went a total of 6100 hours with only pin and bushing replacements . . . and all but the shoes were rebuildable instead of scrap! Up to this point, Custom Track Service saved the stripper a $3298 cash outlay; and since he was able to rebuild the links and reuse the pins and bushings instead of replacing with new assemblies, he realized additional savings.

PAST EXPERIENCE

ALL BUT SHOES READY FOR SCRAP PILE AFTER 2300 HOURS

PRESENT EXPERIENCE

COMPLETELY REBUILDABLE EXCEPT SHOES AFTER 6100 HOURS

HOW CUSTOM TRACK SERVICE HELPS LOWER COSTS

Custom Track Service, available only from your Caterpillar Dealer, is designed to help you get the most possible service from undercarriage parts and thus cut costs. Factory-trained specialists are ready to help solve your particular track problems. They can give sound recommendations to help you get the most from your undercarriage.

They can advise you on maintenance . . . help you tailor the many special undercarriage parts and track options available to meet various job conditions. As a result, costs per hour go down and profit and machine availability go up.

These undercarriage specialists are backed by modern track undercarriage rebuilding facilities manned by experienced personnel . . . by the largest and most complete stock of standard and special application parts available . . . by Parts Exchange Assemblies that keep tractors working and earning.

Check with your Cat Dealer and learn how Custom Track Service can help you to reduce costs.

Caterpillar Tractor Co., General Offices, Peoria, Ill., U.S.A.

CATERPILLAR

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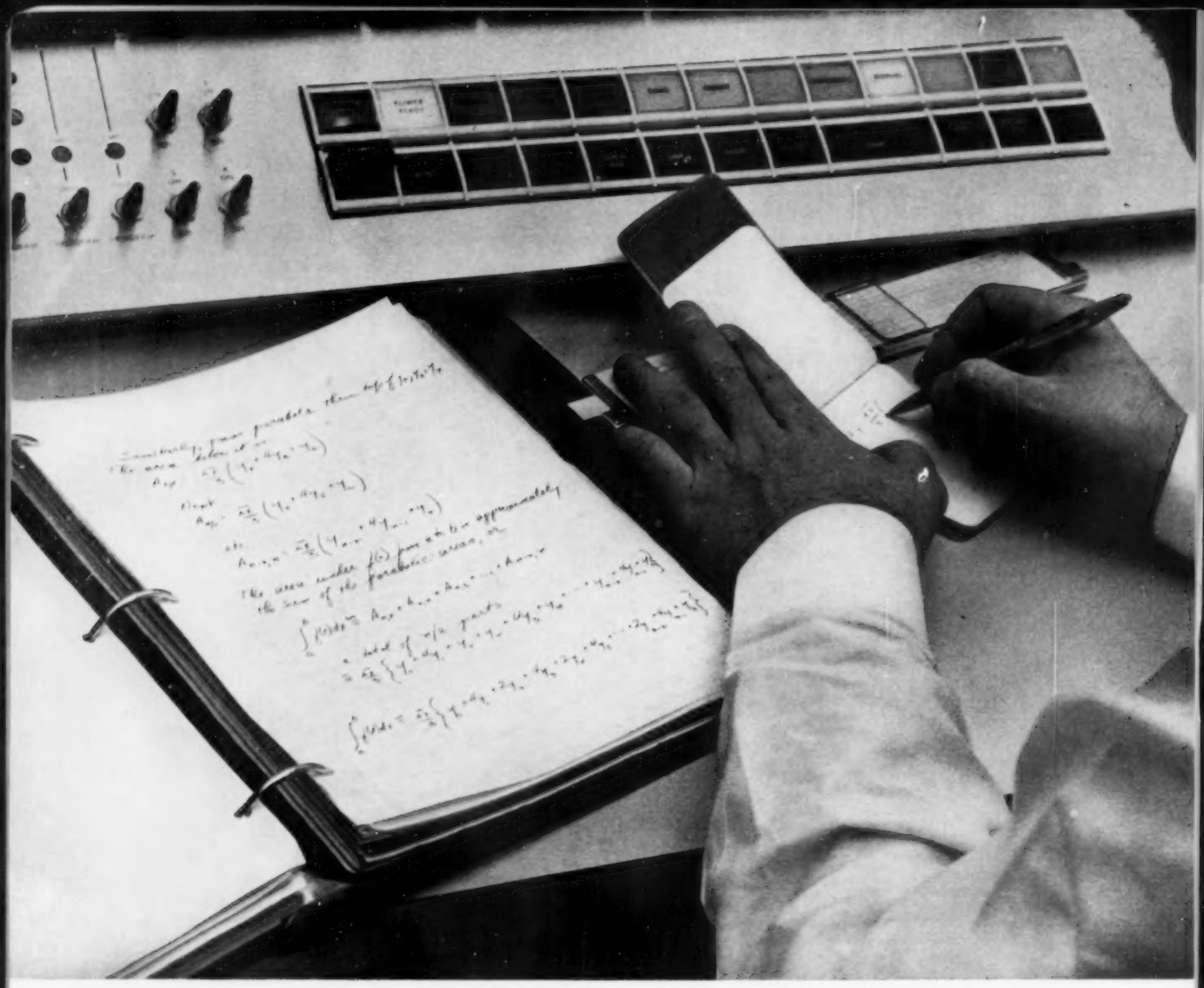


Free engineers for creative assignments with the new low-cost IBM 1620

The IBM 1620 Data Processing System is a low-cost solution to the problem of freeing engineers for their most creative and profitable assignments. Here's why:

EASY TO USE—Just a two-day training class is all you need to put your 1620 into operation. This means no delays in learning to use the 1620 computer.

In addition, you get a wide range of free programming services including FORTRAN and GOTRAN. FORTRAN is the powerful scientific language that lets you solve problems without writing detailed computer instructions. GOTRAN is a simplified language (a sub-set of FORTRAN) that lets you enter simplified problem statements and data into the computer with the solution immediately available, in one simple operation.

FAST—The 1620 solves a set of ten simultaneous equations in only 20 seconds. It inverts a 10 x 10 matrix in just 42 seconds.

POWERFUL—The 1620 inverts a 40 x 40 matrix. With optional additional core storage the 1620 can handle matrix inversion problems of a much higher magnitude.

GET FULL DETAILS—The 1620 is the most outstanding engineering and scientific computer in its price range. A basic installation rents for just $1,600 a month.

To learn how the 1620 can free you for more creative engineering work, call your local IBM representative.

IBM's 1620 is a compact desk-size computer.

IBM®
DATA PROCESSING

NEW Butterfly Valve!

MATCHLESS LUNKENHEIMER QUALITY

FIG. 4026N

Complete Valve with Ends on Casting.
2"-6".
Screwed End.

FIG. 4150N

(Rubber-Lined: Fig. 4151R) Valve Elements Only.
2"-18". Screwed, Welded, Grooved, or Flanged Ends Supplied Separately to Fit Your Pipe Connections.

W. P. 150 psi.

- QUICK OPENING
- POSITIVE CLOSURE
- NICKEL-PLATED CAST IRON
- STAINLESS STEEL TRIM
- "O" RING SEALS

New Lunkenheimer Butterfly Valves are compact and lightweight, easy to install on any line in a fraction of the space required by standard gate or plug valves. A quarter-turn of the stem opens the disc full or closes it tight. No lubrication is required, and "O" Ring seals provide positive shut-off in either vacuum or pressure service. These new Butterfly Valves are made to traditional Lunkenheimer standards of quality. WRITE for new Catalog 613 or call your Lunkenheimer distributor today for full information on the new Lunkenheimer Butterfly Valve line . . . available now for immediate delivery.

L-361-23

LUNKENHEIMER®
THE ONE Great NAME IN VALVES

Why do sweater girls look to the oilman? Simple. He's responsible for the petroleum-based synthetic fibers that go into so many of the sweaters they wear. And for the petroleum-based synthetic dyes that are used to color them. Because of oil research, clothing for the whole family has better appearance and longer life. Each advance in oil technology gives you, the oilman, a greater stake in society. And gives you more reason to speak up when anyone speaks out against oil. Today, everyone enjoys the benefits of oil—one of nature's most versatile resources.

SHELL OIL COMPANY

Measuring News from NLS

NEW WAY TO MEASURE MILLIVOLTS

aboard ship, in the lab, on the production line

A faster, more precise method for making low-level DC voltage measurements is now provided by Non-Linear Systems, Inc., for scientific, industrial and military applications. The new, single-package NLS V60 Digital Millivoltmeter is a full 4-digit instrument that averages 80 measurements per minute for such applications as strain gage and thermocouple measurements, calibrating millivolt devices, process monitoring, and semiconductor research and testing. Because it's a digital voltmeter, the V60 can be read at a glance from close or afar in total darkness or sunlight, without parallax error.

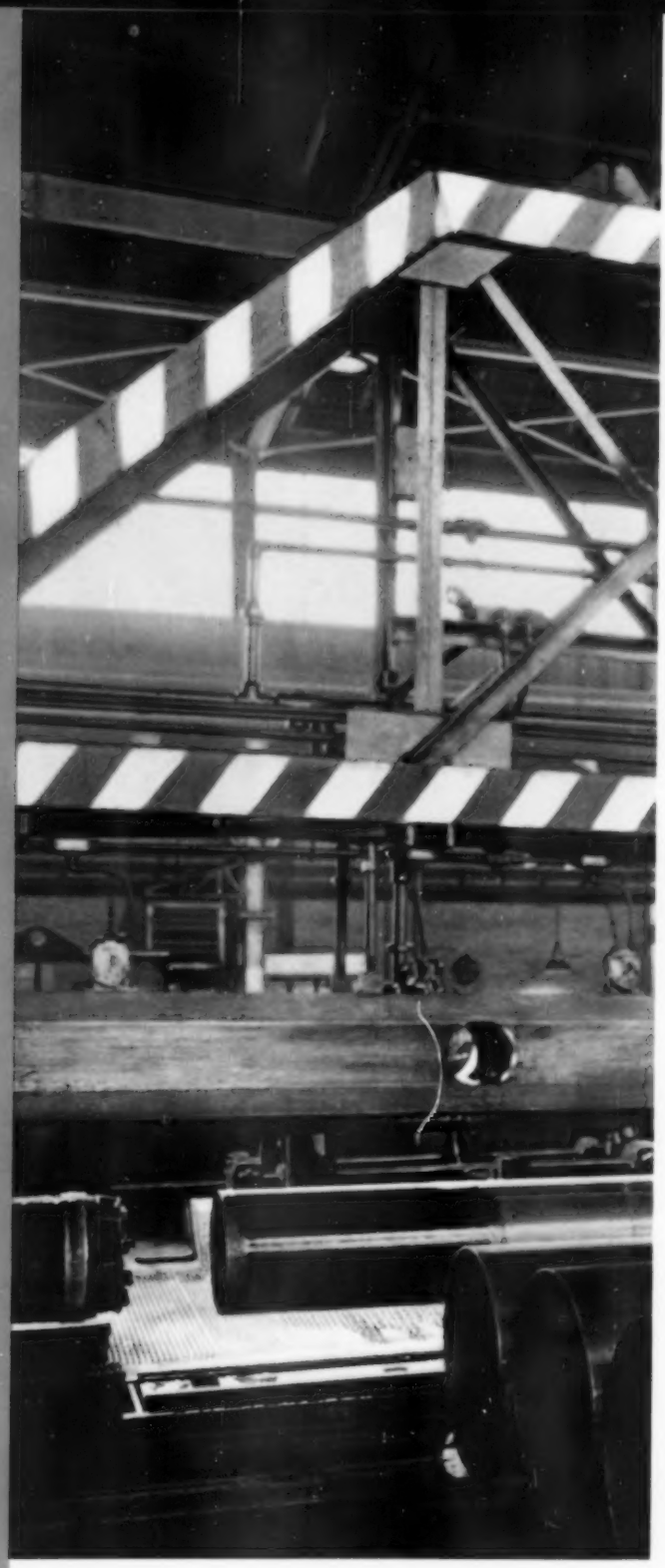
The V60 features ±0.01% precision (ability to repeat readings within close limits) — a degree of precision unattainable from pointer meters, strip chart recorders, or combination of a digital voltmeter and preamplifier. Accuracy is ±0.1% of reading or ±10 microvolts. Range is ±00.01 to ±99.99 mv. A scale factor control allows the V60 to display its readings directly in units of pressure, weight, length, strain, stress, speed, etc. Input impedance is 10 megs at balance. Input terminals are completely isolated from ground, making AC and DC common mode rejection extremely high.

Please contact NLS for additional information on the V60 or any other NLS digital voltmeter.

V60 complete $1,625

non-linear systems, inc. *Originator of the Digital Voltmeter*
DEL MAR, CALIFORNIA

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD



BEND

When you measure performance by the cost per mile, count on line pipe from Youngstown

Work with Youngstown line pipe in the field. String it. Bend it. Cut it. Weld it. Lay it. See how round and straight it is. Watch how it hugs each contour. Line pipe from Youngstown is made to deliver all the characteristics and trouble-free performance that makes your low cost system a far better one.

All Youngstown electric weld line pipe 12¾" O.D. and over is hydrostatically expanded. Brute power of water pressure works the metal, expands it, strengthens it. Each length is given roundness and straightness. Result . . . better welding and bending qualities. And on all Youngstown line pipe, precision tests and quality controls assure the high standards of performance you demand.

Order Youngstown electric weld line pipe in sizes 6⅝" through 22" O.D. Name your coating, if you need one. Order it in faster-laying lengths averaging over 50'. Get fast delivery where and when you want it, through Youngstown District offices, or through 900 independent pipe distributors. For transmission, distribution or gathering systems, always specify line pipe from modern Youngstown, the world's second largest producer of quality pipe.

Youngstown – growing force in steel

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INDUSTRY BUCKS RECESSION

Companies build new paths to profits — slashing costs, widening natural gas and petrochemical sales, seeking more related business opportunities . . .

ERNESTINE ADAMS, *Management Editor*

How did the oil and gas industry fare in 1960?

U. S. petroleum companies climbed out of their old routine last year and put on a superb performance in front of some pretty drab business scenery. To do it took some dieting along with developing some new roles.

Annual reports of 75 companies show a 9% rise in earnings, which follows a gain of 9% last year over 1959.

Just giving those figures would make you think it was easy. They don't reveal the erratic conditions the companies faced.

CHAMPLIN OIL & REFINING COMPANY tells it this way: "Your company's experience in 1960, in common with most corporate units in the petroleum industry, was the reverse of the previous year. Earnings in the first six months of 1960 were adversely affected by chaotic price conditions. A degree of price stability characterized the final six-month period and enabled the industry to develop considerable improvement in operating results despite downward trends in the general economy. Champlin's earnings for the last half exceeded those for the previous six months by 72%."

COLORADO OIL AND GAS CORPORATION reported: "The year should be examined in two distinct operating periods. In the first half we had a loss of 18c per share for the common stock because of the most severe and prolonged disruption of refined product prices in Derby's history. During the last half we made a profit of 61¢ per share as the result of more normal and stabilized product prices and increased oil production."

At least the improvement is encouraging.

Yes, more than the increase implies. If you remember, in the recession of 1958, petroleum companies earnings dropped 21%. In the 1960 general business downturn, profits went up 9%. That's one really important point.

Another one is that profit margins showed some strength. For the second year in a row the margin of earnings to revenues has edged up. Profits were:

7.7% of gross income in 1958;
8.0% in 1959, and
8.3% in 1960.

Also rate of return on investment, which had a small rise in 1959 for the first time since 1951, made another small gain in 1960. Here are the rates for the last 10 years:

1951	16.8%	1956	12.7%
1952	14.6%	1957	11.8%
1953	14.5%	1958	9.0%
1954	13.0%	1959	9.3%
1955	13.0%	1960	9.7%

The graph on the opposite page shows the erosion of profit margins, the recent struggle back.

Was there any special reason why the industry bucked the trend?

Companies in the industry showed their mettle. They didn't stand still. They explored every possible means of reversing the down trend. Here's how one explained to its shareholders:

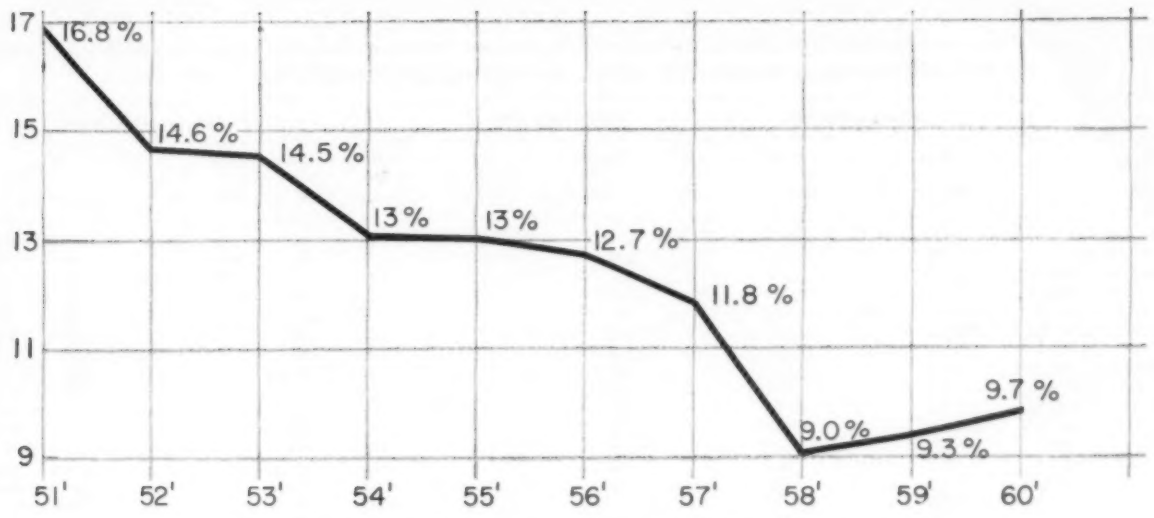
HELMERICH & PAYNE, INC.: "Today we can see the foundation of a diversified operation which will not be solely dependent upon the ultimate demand for crude oil.

"The basic idea of diversification to stabilize and expand earnings is not unique; however, there is a distinction in our acquisition program . . . Our goal is to acquire a complex of operations which will tend to provide a constant source of earnings appreciation."

Among Helmerich & Payne's new acquisitions (outside regular oil and gas production and contract drilling) are Engineering-Construction Company which specializes in gas distribution systems, Natural Gas Odorizing, supplier of odorants for natural and liquefied petroleum gases.

At the same time that some were trying to offset almost static crude oil markets, companies like PRODUCING PROPERTIES used this as an advantage. Said its report: "Major growth has occurred during a period of constantly deteriorating conditions in the producing segment of the petroleum industry. The management feels the present situation of low allowables and depressed crude prices may continue for from two to five years more. During that time it is expected that many attractive purchases will be made. Thus, the remarkable growth of the corporation in net reserves and future net revenue must be recognized eventually."

PUBCO proved a new producing company can still make it the exploration way. It has increased its sales of oil and gas every year since 1955 and next year plans to accelerate its exploration and development drilling program with



RATE OF RETURN ON INVESTMENT *edged up in 1959, showed more strength last year. This is a significant reversal after seven years of sliding.*

its biggest capital expenditures budget — $3.5 million.

In the opinion of STANDARD INDIANA: "With the continuing encroachment of price-controlled natural gas on our fuel oil sales, and the increasing popularity of small automobiles which use less gasoline and lubricants, growth in oil demand will be slower in the future than in the recent past unless new uses are developed. We are searching for new uses both in our own laboratories and in cooperation with others. We have set up a new planning department to help lay out a long-range program for the company and assess investment opportunities in the petroleum business and other fields which can be related to our present activities."

ASHLAND OIL AND REFINING reported: "The principal business of your company always has been the transportation and refining of crude oil and the marketing of petroleum products. These continue to be our most important operations, but over the last few years we have become more active in the discovery and production of crude oil and in the manufacture of petro-chemicals and similar products. Our success in these fields of increased activity enables us to report the second largest earnings in the history of the company."

Mergers and acquisitions kept making little and big companies bigger with a goal to greater operating efficiency and diversity.

TEXAS NATIONAL PETROLEUM COMPANY: "Texas National Petroleum will remember 1960 as the year of the big change, changing from a small independent oil and gas company to a company of significant stature.

"Though the acquisition of Utah Southern Oil Company and the merger of Petro-Minerals, Inc. into TNP, account for the major changes, it is pleasant to report that these new properties are performing better than originally indicated by our engineering estimates."

ATLANTIC REFINING'S statement points to the changing patterns of the industry: "It is important to report that Atlantic, as it ended 1960, is a different kind of company than it was a decade ago. Significant strengths have been built into the company. The most important of these are self-sufficiency in raw materials, a better product mix and substantial reductions in operating costs."

SKELLY OIL "pursued several avenues of opportunity." One described was: "Our uranium exploration program has resulted in discovery of a substantial deposit of uranium ore in the Shirley Basin, Carbon County, Wyoming. Skelly and three other companies have formed a partnership known as Petrotomics Company, which is now engaged in open-pit mining operations in this area. Construction of a mill for processing uranium ore will be commenced by Petrotomics Company during 1961. Contracts have been signed providing for the sale of uranium ore and concentrate through 1966."

SUN OIL'S report named four factors primarily responsible for its improved earnings: "A continued attack on costs, development of manufacturing capabilities and markets for products which yield a higher return on the processing of crude oil, greater selectivity in selling, and increases in the production of crude oil and natural gas."

All these reports emphasize the endless variety of ideas and actions that each company management put into use in 1960.

There is heavy stress on cost-cutting. Just exactly what does it mean?

Actually cost reductions are gained through improved organization and operation and improved equipment. Here are examples:

QUAKER STATE reports it reviewed plant costs at all levels throughout the year and "benefits accrued from a sound maintenance and repair program."

SOHIO: "In transportation, emphasis on cost reduction and automation of pipeline operations was continued with good results for 1960. Several small isolated pipeline gathering systems were sold to avoid incurring increasing costs."

AMERICAN PETROFINA: "A pronounced reduction in cost of transportation of refined products was effected during the year through the replacement of a substantial portion of the company's truck and trailer units with new and larger capacity equipment and by the maximum utilization of its large railroad tank car fleet.

"The wholly owned American Liberty Pipe Line system, which delivers crude oil to the Mt. Pleasant refinery, was further expanded during 1960

TABLE 1. FINANCIAL STATISTICS OF U. S. PETROLEUM COMPANIES FOR 1960.

Company	Income—Add (000) Gross 1960	Gross %	Net 1960	Net %	Taxes—Add (000) Direct 1959	Direct 1960	Excise 1960	Common stock 1000 shares	Per common share issued: Price 12/31 1960	Equity 12/31 1960	Net income	Taxes*	Dividends
Ambassador	$ 6,728	+ 7	$ 1,086	+ 26	$ 341	$ 378	—	$ 3,687	4	$ 3.08	$ .27	$ .10	none
Amerada Pet.	102,445	0	27,569	+ 7	7,049	7,222	—	6,313	69⅞	29.91	4.37	1.14	2.15
American Petrofina	73,829	— 4	1,232	+ 21	1,536	1,527	—	6,977	5	8.58	.18	.22	.15
Anderson-Prichard	75,277	+ 4	5,292	— 23	2,230	2,836	9,693[12]	1,754	46⅝	34.72	2.79	1.62	.70
Argo Oil Corp.	14,863	+ 6	4,891	+ 12	897	1,617	—	2,000	39⅛	20.74	2.54	0.81	1.48
Ashland Oil & Ref.[3]	303,673	+ 1	14,927	+ 4	12,830	10,975	—	6,580	22⅜	20.19	2.12	1.67	1.00s
Atlantic Ref. Co.	561,205	+ 4	46,566	+ 54	20,899	24,649	100,233	9,054	43	56.19	5.00	13.79	2.00
Aztec Oil & Gas	8,169	— 2	4,514	— 12	425	576	—	2,640	54¾A	8.29	1.71	0.22	5%s
Bishop Oil Co.	1,885	— 11	(624)	—	98	97	—	456	7⅞	8.45	(1.37)	0.21	none
Champlin Oil & Ref.	74,270	+ 3	9,157	+ 7	3,538	4,600	10,153	4,131	21¾	18.67	2.14	3.57	1.00
Cities Service	995,721	— 1	41,320	— 3	26,178	36,323	147,054	10,729	51⅞	62.24	3.85	17.09	2.40
Clark Oil & Ref.	86,930	— 4	1,906	— 10	4,573	2,471	—	1,626	12A	12.24	1.17	1.51	6%s
Coastal States[1]	17,586	+ 70	2,951	+ 86	203	253	—	1,941	62¼A	4.24	1.52	0.13	none
Colorado Oil & Gas	46,702	+ 2	1,846	— 27	990	960	4,862	3,140	10⅜	8.46	0.43	0.31	none
Continental Oil	799,145	+ 2	61,233	+ 2	35,901	28,753	94,701	21,139	56	24.05	2.90	5.84	1.70
Cosden Pet. Corp.[2]	83,293	0	4,763	+ 6	4,079	4,388	10,253	2,983	18¾	14.50	1.60	1.47	1.00s
Delhi-Taylor	98,354	+ 14	3,717	+ 37	1,175	1,250	—	5,177	14⅞A	4.54	.72	0.24	none
Douglas Oil Cal.[5]	31,412	+ 2	1,013	+332	(171)	709	—	1,223	9¼	5.88	0.83	0.58	none
Drlg. & Expl.	9,456	— 6	775	+2½	105	85	—	1,896	8½	9.00	0.409	0.04½	0.25
Eason Oil Co.[4]	3,709	— 1	222	— 44	119	114	—	364	12½A	19.84	0.61	—	0.20
General American[1]	27,958	+ 8	2,196	— 67	65	40	—	3,358	20⅞	23.43	0.66	0.59	0.40s
General Crude	12,137	— 10	2,216	— 34	1,339	752	—	1,932	23A	13.52	1.15	0.39	1.00
Getty Oil	62,625	+ 13	10,822	+ 2	—	—	—	15,987	58⅛	23.95	0.68	—	none
Gulf Oil Corp.	3,212,205	+ 1	330,311	+ 14	193,792	210,244	491,395	103,143	37	27.73	3.20	6.80	1.00s
Helmerich & Payne[3]	13,749	— 5	707	+117	375	393	—	1,745	7⅞	4.82	0.41	0.22	0.05
Honolulu Oil	47,412	+ 5	10,363	— 20	4,443	4,569	—	3,751	65⅛	25.25	2.77	1.22	2.00
Hugoton Prod. Co.	6,595	— 11	3,081	— 11	2,072	1,761	—	851	84¾	—	3.62	—	3.00
Kern Co. Land	96,807	0	15,733	— 5	9,499	8,545	—	4,316	53	20.58	3.64	1.98	2.40
Kerr-McGee[1]	157,785	+ 18	7,287	+ 24	2,970	6,228	33,919	2,406	64½	27.36	2.71	2.59	1.20
Leonard Ref.	55,890	+ 3	1,807	+ 34	3,874	4,305	3,239	1,176	11⅛	15.88	1.54	6.41	0.47
La. Land & Exp.	44,278	+ 15	22,819	+ 18	13,091	15,334	—	8,975	62⅛	5.17	2.54	1.71	1.80
Midwest Oil Corp.	20,716	0	7,341	0	2,221	2,483	—	2,459	39½	17.58	2.99	1.01	1.77
Murphy Corp.[5]	57,340	+ 14	2,867	+ 10	1,928	2,414	—	3,341	20¼	20.86	0.86	—	—
Ohio Oil Co.	357,778	+ 2	39,215	+ 2	12,426	12,266	50,370	13,807	37⅛	30.41	2.84	4.54	1.60
Olin Oil & Gas	47,001	+ 11	3,482	— 3	3,681	3,745	—	2,830	15½	7.06	1.20	1.32	0.50
Pauley Pet.[6]	10,461	+ 36	395	— 46	444	436	—	1,946	14⅝A	8.70	0.20	—	none
Permian Corp.	33,262	+ 88	583	+ 26	—	—	—	600	—	—	0.97	—	—
Phillips Pet.	1,228,600	+ 4	112,900	+ 8	83,531	84,273	125,000	34,358	53⅞	32.22	3.29	6.09	1.70
Plymouth Oil	76,721	— 15	(2,446)	—	1,100	1,156	—	2,646	20¾	20.02	(.92)	—	0.50s
Prod. Properties[7]	9,694	+ 19	1,759	+163	459	798	—	2,600	5⅝A	2.78	0.62	—	none
Pubco	2,422	+ 7	647	+ 27	—	135	—	3,144	7½A	2.83	0.21	0.04	none
Pure Oil	654,450	+ 5	32,555	+ 12	10,905	15,124	124,316	9,894	34⅝	44.19	3.29	14.09	1.60
Quaker State	54,061	— 2	1,791	— 25	3,050	2,075	—	927	27½	32.69	2.17	2.52	1.60
Republic Nat'l Gas[1]	18,432	+ 8	5,704	+ 40	250	675	—	2,999	29⅜	13.63	1.90	0.23	0.80
Richfield Oil Corp.	368,069	+ 8	28,720	+ 2	20,633	27,729	79,109	4,039	88¼	64.54	7.11	26.45	3.50
Shamrock O & G	66,270	+ 16	10,457	+ 14	2,791	2,935	—	3,481	43½	16.64	3.00	0.84	1.60
Shell Oil	1,827,832	+ 1	144,588	— 2	98,948	93,401	340,000	60,573	39⅜	23.16	2.39	7.16	1.10
Signal Oil & Gas	305,559	+ 57	16,509	+1½	2,792	3,754	42,575	9,887	22⅝	20.00	1.67	0.96	0.80s
Sinclair Oil Corp.	1,237,823	— 1	52,547	+ 17	48,028	56,996	256,461	15,351	38¾	62.05	3.42	3.71	2.50
Skelly Oil	256,625	— 1	24,415	— 9	13,528	13,427	30,506	5,654	45⅜	62.48	4.32	2.37	1.80
Socony Mobil	3,645,700	+ 4	182,610	+ 11	144,000	179,000	402,000	48,601	39¼	53.62	3.76	11.95	2.00
Southland Royalty	9,562	— 4	3,757	— 9	2,314	2,086	452	847	58¼	21.80	4.44	2.46	3.00s
South Penn Oil	59,396	+ 4	3,491	+ 5	3,186	2,862	5,686	1,703	29¼	31.54	2.20	5.02	2.00
Standard Oil Cal.	1,922,000	+ 7	266,113	+ 5	87,530	101,741	259,072	63,224	48⅛	35.74	4.21	1.61	2.00
Standard Oil Ind.	2,005,816	+ 3	144,762	+ 4	81,003	86,841	423,495	35,770	47⅛	62.93	4.05	14.27	1.995[12]
Standard Oil N.J.	8,915,004	+ 2	688,573	+ 9	968,000	958,000	661,000	216,533	41¼	31.54	3.18	7.48	2.25
Standard Oil Ohio	402,443	+ 1	24,662	— 2	19,926	23,037	111,888	4,855	54	56.33	4.94	4.75	2.50
Sun Oil Co.	755,426	+ 1	49,273	+ 15	42,083	42,720	194,255	13,047	47⅝	47.35	3.78	19.96	1.00s
Sunray Mid-Cont.	467,218	+ 3	41,121	— 6	23,435	26,029	49,495	17,914	23⅝	22.61	2.10	4.22	1.32
Sunset Int'l[7]	10,866	+ 89	1,200	+139	—	—	—	5,348	3½	3.32	0.21	—	s
Superior Oil[6]	130,534	— 1	21,602	+ 12	12,742	12,474	—	422	1210	408.48	408.48	51.19	7.50
Tekoil Corp.[5]	2,541	+ 15	(686)	—	—	—	—	1,173	2¾A	4.36	(0.58)	0	—
Texaco, Inc.	3,140,805	+ 11	391,751	+ 11	141,868	147,393	539,816	61,749	85⅜	44.32	6.34	14.20	2.85s
Texas Gulf Prod.	18,296	+ 4	4,700	+ 12	2,633	2,985	—	4,043	28	11.48	1.16	0.74	0.60
Texas Nat'l Pet. Co.	6,041	+115	490	+110	—	158	—	3,732	2⅝	3.99	0.13	—	none
Texas Pacific Coal	26,234	0	7,778	+ 8	2,038	2,123	—	3,883	28	20.49	2.00	0.55	1.20
Three States Gas	5,120	— 5	593	+386	334	330	205	6,500	2¾A	1.31	0.09	0.08	none
Tidewater Oil	583,150	+ 4	35,063	+ 3	20,028	20,795	122,355	14,493	20.75	30.94	2.22	1.43	5%s
TXL Oil Corp.	12,505	— 4	2,855	— 30	1,320	1,702	—	5,574	17⅝	6.32	0.51	0.31	none
Union Oil Co. Cal.	535,631	+ 4	34,478	+ 25	21,290	25,278	91,955	8,710	44	54.16	3.96	13.46	1.75
Union Tex. Nat'l G	82,084	+ 3	14,173	— 20	7,170	8,646	—	7,042	29⅝A	12.17	2.01	1.23	0.40
Universal Cons. Oil	7,041	— 9	2,007	— 5	1,256	1,224	—	948	31	20.71	3.07	1.29	2.60
Wilcox Oil	5,961	— 16	840	— 14	257	271	521	322	45	36.20	2.61	0.84	1.00s
TOTALS	$36,514,583	+ 3%	$3,047,834	+ 8%	2,243,643	$2,351,471	$4,816,034	—	$3581⅞	$2065.07	$205.82	$279.21	$84.69

( ) Loss
*Excise taxes included for marketing companies; import duties are not.

A Asked
S Stock dividend
1. Fiscal year ending June 30
2. Fiscal year ending April 30
3. Fiscal year ending September 30
4. Fiscal year ending July 31
5. Fiscal year ending March 31

TABLE 2. CAPITAL ASSETS, CHARGE-OFFS, AND CAPITAL EXPENDITURES.

Company	Years in business	At end of fiscal 1960: Gross fixed assets ($1000)	Net fixed assets ($1000)	Working capital ($1000)	Long term debt ($1000)	Net worth ($1000)	Return on net worth, %	Charge-offs[11] ($1000)	Capital and exploration outlays ($1000): 1959	1960	1961 Est.
Ambassador Oil	5	19,487	13,410	(924)	2,427	11,356	8.9	1,764	6,644	4,300	5,000
Amerada Pet.	40	485,895	116,900	67,283	none	188,814	14.6	31,980	42,625	40,450	—
American Petrofina	5	102,614	65,256	10,825	19,407	59,874	2.0	6,669	7,647	5,762	—
Anderson-Prichard	39	128,989	69,857	17,510	21,900	69,879	7.6	6,640	13,187	11,295	—
Argo Oil Corp.	24	55,029	26,751	4,245	none	41,479	11.8	1,979	4,963	6,059	6,500
Ashland Oil & Ref.[8]	37	251,300	97,624	51,920	37,984	132,869	11.2	15,761	16,868	26,044	—
Atlantic Ref. Co.	90	1,115,902	617,732	83,948	176,875	543,908	8.8	52,203	79,000	87,629	—
Aztec Oil & Gas	7	32,093	24,829	1,361	4,975	21,885	20.6	5,360	5,522	6,119	7,000
Bishop Oil Co.	33	11,525	4,984	58	1,348	5,896	10.6	1,364	—	300	16,800
Champlin Oil & Ref.	19	194,869	88,100	13,504	27,861	77,129	11.9	8,971	20,836	14,452	—
Cities Service	51	1,498,399	812,792	296,720	446,031	667,831	6.2	84,136	99,075	129,399	—
Clark Oil & Ref.	27	27,289	16,686	5,150	2,280	19,915	9.6	1,878	1,332	1,056	—
Coastal States Gas[1]	5	39,077	35,145	4,284	31,190	8,581	34.4	1,404	13,434	15,698	19,800
Colorado Oil & Gas	9	79,043	48,485	9,526	18,159	36,804	5.01	4,556	6,770	6,823	6,155
Continental Oil	86	1,107,654	389,827	96,944	131,587	508,457	12.0	74,799	98,994	142,620	133,000
Cosden Pet.[2]	21	72,660	45,957	9,756	12,080	43,266	11.0	5,746	6,850	8,603	12,209
Delhi-Taylor	15	77,252	43,257	12,247	45,002	23,516	15.8	6,775	4,400	12,800	6,400
Douglas Oil Calif.[5]	14	13,651	6,494	2,522	3,658	7,183	14.1	1,062	1,310	1,300	—
Drlg. & Exp.	31	32,233	13,123	3,356	none	17,307	5.5	2,205	3,991	3,333	3,000
Eason Oil Co.[4]	47	14,401	6,588	672	113	7,223	3.1	835	867	1,394	—
General American[1]	25	217,122	76,949	10,449	20,070	78,691	2.8	8,146	22,306	67,960	—
General Crude	31	51,188	16,452	9,660	none	26,112	8.5	4,535	6,752	7,574	7,130
Getty Oil	32	135,518	75,741	15,815	18,605	72,951	14.8	7,894	10,430	—	—
Gulf Oil	60	4,629,712	2,185,056	781,185	257,385	2,859,677	8.6	283,017	437,000	452,491	Up 15%[8]
Helmerich & Payne[3]	41	35,147	16,737	2,248	10,020	8,405	8.4	3,093	3,728	4,602	3,895
Honolulu Oil	51	166,769	75,817	17,405	none	94,703	11.0	9,693	16,700	22,734	—
Hugoton Prod.	11	10,360	7,875	3,980	none	12,355	25.0	269	330	698	580
Kern Co. Land	—	—	49,823	37,565	2,525	88,925	17.7	3,694	17,718	15,527	—
Kerr-McGee[1]	29	169,846	113,949	30,065	67,541	82,687	8.8	11,820	29,767	24,623	28,377
Leonard Ref. Inc.	25	26,603	15,776	7,601	3,487	18,666	9.7	1,796	918	1,490	3,045
La. Land & Exp.	35	42,423	27,942	18,423	none	46,366	49.2	2,560	5,883	4,885	4,500
Midwest Oil Corp.	50	93,897	37,072	5,963	none	43,229	17.0	2,698	7,530	7,640	9,798
Murphy Corp.[6]	10	123,792	84,691	16,697	33,032	69,694	4.1	4,289	16,626	23,219	17,930
Ohio Oil	73	733,685	326,929	79,383	6,050	419,883	9.3	27,228	84,287	92,774	90,387
Olin Oil & Gas	7	88,262	37,048	4,505	17,776	22,488	15.5	3,275	—	5,418	5,679
Pauley Petroleum	7	19,782	13,609	1,373	19,258	16,921	2.3	3,377	—	705	—
Phillips Pet.	43	2,013,460	1,079,558	195,707	279,200	1,646,807	6.9	139,500	120,805	180,654	—
Plymouth Oil	37	118,433	53,290	14,346	15,451	53,025	—	10,022	6,421	4,939	7,375
Producing Prop.[7]	6	55,044	20,546	2,442	11,212	10,368	17.0	3,686	10,050	13,830	15,000
Pubco	7	9,835	7,374	1,534	none	8,147	8.0	674	—	1,500	3,800
Pure Oil Co.	47	761,592	380,161	129,308	80,775	428,694	7.6	33,120	44,452	60,026	43,000
Quaker State	30	28,177	11,266	12,402	none	26,970	6.6	1,680	1,684	1,649	—
Republic Nat'l Gas[1]	25	67,170	38,238	6,631	4,000	40,869	14.0	2,265	5,730	7,003	—
Richfield Oil	49	547,040	257,649	117,877	136,403	260,668	11.0	29,617	63,219	66,380	—
Shamrock O. & G.	32	135,013	88,119	6,765	38,469	57,915	18.1	6,685	13,958	20,870	13,817
Shell Oil	39	2,912,786	1,136,893	298,216	200,002	1,403,066	10.3	201,020	280,073	353,874	363,000
Signal O. & G.	38	327,796	181,816	38,237	50,351	199,112	8.3	145,980	27,500	41,110	45,265
Sinclair Oil	45	1,799,014	902,302	313,994	363,874	940,170	5.6	85,595	124,380	121,223	174,900
Skelly Oil	41	663,915	297,099	56,466	3,347	353,250	6.91	39,388	60,395	59,742	—
Socony Mobil	78	3,779,985	1,870,498	732,511	168,214	2,605,902	7.1	229,357	357,000	320,111	350,000
Southland Royalty	36	22,295	10,431	8,035	none	18,485	20.3	749	—	2,000	—
South Penn Oil	71	133,901	27,163	21,006	none	50,145	6.96	3,668	6,913	7,031	—
Standard (Calif.)	82	3,371,705	1,864,009	429,800	172,800	2,259,690	11.8	152,198	399,992	369,936	[8]
Standard (Ind.)	72	3,531,794	1,976,135	582,724	423,891	2,251,085	6.4	199,504	346,000	340,000	[9]
Standard (N. J.)	78	10,265,000	6,061,000	1,758,416	807,791	6,829,181	10.1	540,735	926,146	919,218	1,100,000
Standard (Ohio)	91	496,764	250,885	79,202	52,124	291,748	8.5	26,743	40,435	34,736	41,600
Sun Oil Co.	75	947,704	493,118	131,446	23,609	617,819	8.0	63,329	132,700	106,600	131,000
Sunray Mid-Cont.	41	860,114	428,837	91,671	51,023	472,832	8.7	31,079	67,661	61,693	70,475
Sunset Internat'l.[7]	—	26,147	18,836	1,778	22,585	17,736	6.8	1,100	—	—	—
Superior Oil	40	332,901	221,137	37,094	85,850	172,381	12.5	39,736	56,749	32,402	—
Tekoil Corp.[5]	—	14,409	10,084	340	4,018	5,109	—	1,253	—	1,396	—
Texaco, Inc.	59	4,501,684	2,220,251	681,804	335,923	2,736,715	14.3	256,091	517,870	521,103	[10]
Texas Gulf Prod.	30	82,289	41,548	13,647	8,770	46,425	9.5	4,066	10,203	8,775	12,000
Texas Nat'l. Pet.	5	38,330	34,031	(821)	19,603	14,884	3.3	1,708	—	—	—
Texas Pacific	72	117,163	67,853	11,575	none	79,545	9.8	4,840	11,919	9,420	—
Three States N. Gas	9	26,307	15,354	2,790	9,629	8,515	7.0	1,184	3,416	1,950	500
Tidewater Oil	82	1,238,730	689,478	86,604	311,305	448,474	7.17	60,598	100,069	112,804	[10]
TXL Oil	6	40,468	27,484	7,739	none	35,223	8.1	3,109	8,791	8,000	10,500
Union Oil Calif.	70	1,044,016	482,761	140,331	176,570	471,703	7.3	63,809	90,215	101,846	98,500
Union Texas Nat'l Gas	66	191,964	116,505	3,299	28,598	85,679	16.5	11,582	17,668	36,535	—
Universal Consol Oil	39	27,855	12,631	7,001	none	19,632	14.8	1,261	1,051	1,500	1,500
Wilcox Oil	43	18,932	8,257	2,901	none	11,657	7.2	717	1,943	1,201	1,000
TOTALS		52,453,200	27,097,859	7,758,042	5,324,013	31,434,551		3,091,119	4,953,006	5,188,833	3,390,782

6. For 7 months ending December 31
7. Fiscal year ending August 31
8. Estimate more than $400,000,000.
9. Estimate more than $300,000,000.
10. Approximately same as 1960
11. Intangibles may be amortized
12. Includes market value of Jersey Standard stock dividend.
13. Federal only.

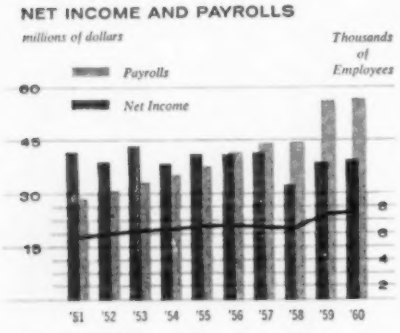
to gather crude from the Trix-Liz multi-pay field in East Texas. The latest automatic metering and gathering devices were employed on several leases in this field resulting in a reduction of gathering costs."

SHELL: "In its manufacturing capital expenditures program, the company continued to emphasize product upgrading and quality improvement, together with operating economy, rather than expansion of capacity."

PHILLIPS: "Our special program for evaluation of undeveloped oil and gas leases in the United States was virtually concluded. This program in four years not only eliminated holdings of minimum promise, with a savings of approximately $3,500,000 or 50% in annual lease rental costs, but also brought many acreage blocks into productive status."

BISHOP OIL: "A program of orderly disposal of certain properties has been followed which will enable the company to concentrate its efforts on more profitable leases."

SOUTH PENN OIL COMPANY stated one of its most serious problems was



OHIO OIL *shows three trends in last 10 years: (1) Number of employees (black line) increases slowly; (2) Net income moves slightly down; (3) Payrolls rise substantially.*

increasing labor demands. Explanation was: "Your company is not able to obtain decrease in costs through automation to the extent of companies not primarily engaged in the manufacture of lubricants because the development of automatic packaging and packaging lines has not increased to the extent of automation in other areas of petroleum refining."

SUNRAY MID-CONTINENT emphasized "Training for Efficiency" with this statement: "Constant attention was given throughout the year to more efficient unit operations, to savings on chemicals, materials and catalysts and to maximum utilization of personnel. New applications of refinery engineering, yield programs and manual operations were placed on the company's electronic computer to effect substantial savings."

In what area did the industry make its best gains?

No question about that — petrochemicals brought in 22% more revenues for our list of firms than in 1959. This compares with just 1% increase in dollars from crude oil sales. In 1959 the petrochemical rise was about 20% above 1958. No wonder this branch of petroleum was becoming more and more the glamour side of the business. Some companies were just getting in.

PURE OIL: "For some years Pure has been conducting studies of profit potentials in the petrochemical industry. Recent developments have demonstrated the desirability of further penetration of this field. We have contracted for the construction and operation of a jointly-owned plant adjacent to our Smiths Bluff Refinery near Beaumont, Texas, which will produce benzene, toluene, and xylene — all basic products with wide application in industry."

UNION TEXAS NATURAL GAS: "The company is actively studying entry into the petrochemical field in order to upgrade the value of a portion of its large supply of natural gas liquids."

PLYMOUTH OIL: "This program of planning ahead was not restricted to production and exploration. In its endeavor to keep up with new and expanding markets for petrochemicals, the company has entered that field by authorizing construction of a new Udex aromatic extraction unit at its Texas City refinery. The company has already entered into a contract for the sale of all the benzene produced by this unit for the next three and one-half years."

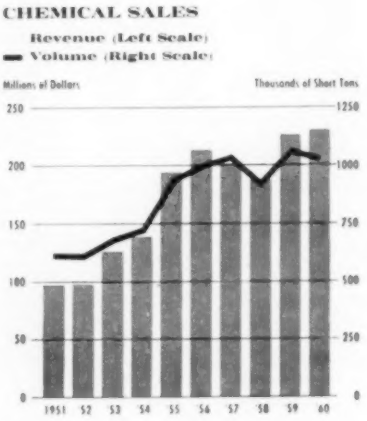
TIDEWATER: "Plans for expansion of petrochemical manufacture at the Avon and Delaware refineries were announced during 1960. A section of the Delaware refinery property has been designated a 'Petrochemical Park.' This early planning will permit an orderly development and expansion of these petrochemical activities. Similarly, an area for petrochemical development is available at our Avon, California, refinery."

CLARK OIL & REFINING: "Seriously being considered are plans for the addition of facilities at our refinery to manufacture petrochemicals from which many of today's consumer products are made. Although petrochemicals account for but a relatively small percent of the crude oil refined, they represent a significant avenue of diversification and profit. Demand has steadily risen in the past few years and the outlook is for further spectacular gains."

SOCONY MOBIL embarked "on a long-range program to acquire a substantial position in the rapidly growing chemical field." Mobil Chemical Company was established "as a separate operating division to handle Socony Mobil's world-wide chemical business.

"The petrochemical segment of the chemical industry makes more than 2500 different chemicals from oil and gas and already accounts for 30% of the physical volume of the chemical industry's production and 60% of its dollar volume. It is also the fastest-growing part of the chemical business, with petrochemical output expected to rise at an annual rate of 7% to 8% during the next 10 years.

"Socony Mobil's chemical division aims to build a strong position in this expanding business."



SHELL OIL, *leader in chemicals, pictures its growth for 10-year period both in volume and revenue.*

GULF OIL: "During 1960, petrochemical operations continued to expand for the eighth successive year, and contributed significantly to Gulf's improved earnings. Sales were 29% above those of 1959; and ethylene continued to be the chief product. Sales of other petrochemical products reached new high levels.

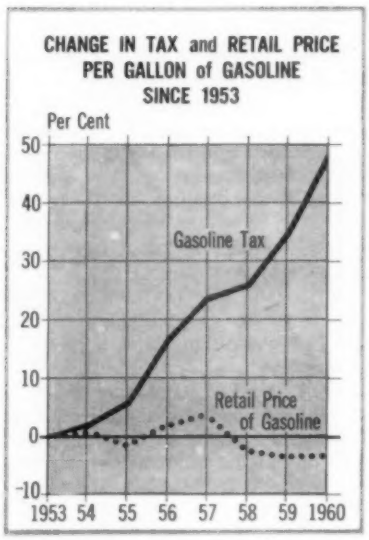
"Export sales also attained record highs. Gulf sold propylene tetramer to manufacturers of detergent raw

materials; benzene to manufacturers of detergent and plastic raw materials; cyclohexane to nylon manufacturers; heptene to manufacturers of oxo alcohols; and toluene to makers of plastics and solvents in South America, Europe, and Asia."

If crude oil dollar sales were only 1% ahead of 1959, what about oil products — did they do much better than crude oil?

This is going to surprise you. Oil products sales brought in only 1.2% more gross income in 1960 than in 1959. The dollar volume didn't increase here much either. Natural gas sales went ahead a sound 10.4% and LPG advanced.

UNION TEXAS NATURAL GAS (merger of Union Oil & Gas of Louisiana and Texas Natural Gasoline, with Anderson-Prichard properties added): "Production of natural gas liquids in the United States is expanding more rapidly than the production of either oil or gas. In 1960 consumption of LP-gas by domestic and commercial customers



SUN OIL *report shows one reason gasoline sales are down. Rising taxes and sagging prices tell story of gasoline over past seven years.*

increased more than 10% as compared with the prior year. The use of LP-gas as a raw material for the manufacture of petrochemicals rose 20% over 1959. As compared with these nationwide increases the production of LP-gas by the company in 1960 showed a gain of 24%."

Some spectacular gains were chalked up by individual companies in natural gas sales.

AZTEC OIL AND GAS, growing young company which had its first setback in income, nevertheless showed a 30% increase in natural gas sales.

ARGO OIL, a producing company with an 11% rise in earnings, had a 35% increase in gas sales in 1960 over 1959.

LOUISIANA LAND AND EXPLORATION had an increase in gas sales of 51% (by mcf/d) and this followed a 40% rise in 1959 over 1958.

GENERAL AMERICAN OIL COMPANY OF TEXAS, which tripled its natural gas sales, reported: "Of outstanding importance was acquisition of significant natural gas reserves which, when added to discoveries, increased the company's holdings to an estimated 746.5 billion cu ft. The company's announced goal of increasing its gas reserves to a trillion cubic feet by 1965 appears well on its way toward realization."

Expansion of natural gas production and sales is hardly new, would you say?

Certainly not, although the persistent expansion under the frustrating conditions of federal red tape is surprising. You wonder what would have happened if natural gas independent producers hadn't been tied up by federal controls. Also natural gas has opened up a new kind of company which is in the business of operating natural gas gathering and distribution lines.

COASTAL STATES GAS PRODUCING COMPANY has made dramatic gains in its short five years. It explores for and produces oil and gas, expands its gas gathering system, gathers its own and purchased gas and sells to transmission companies.

OLIN OIL AND GAS CORPORATION is an active producer and transporter of natural gas. It gathers gas from Louisiana fields and sells principally to industrial consumers in the same area. The company was admitted to listing on the New York Stock Exchange in 1960.

DELHI-TAYLOR added the gas-gathering business to its wide-spread activities in 1960 through a subsidiary. The new gathering line consists of 69 miles of high pressure pipe ranging from 4 to 16 in., with 100,000 mcf/d capacity. Gas is sold to a large transmission company.

What about foreign operations? Have they expanded?

Nearly every company on our list of 75 have operations outside the U. S. Returns on investment show up well.

JERSEY STANDARD report points out that in 1960 American companies returned $2.4 billion income to U. S. from all investments abroad. During the same time funds sent abroad for new investments amounted to $1.5 billion.

Indications are that capital expenditures for foreign operations this year will show a higher increase over 1960 than domestic outlays. Here are some reasons:

TEXAS GULF PRODUCING has concessions in Libya where portions must be surrendered at certain periods. Good oil fields have been discovered on two of these. Four rigs are hard at work evaluating the Libyan concessions.

AMERADA bases its prediction of higher income on increased oil and gas production in Canada "resulting primarily from the development drilling planned for 1961; and of major importance, although not expected until the second half of 1962, commencement of oil sales from Libya."

Contract drilling — from annual reports — owes better figures to foreign operations:

DRILLING AND EXPLORATION: "Operations abroad continued to be satisfactory, and earnings in the foreign division enabled Drilexco's contract drilling subsidiaries to show an operating profit for the year."

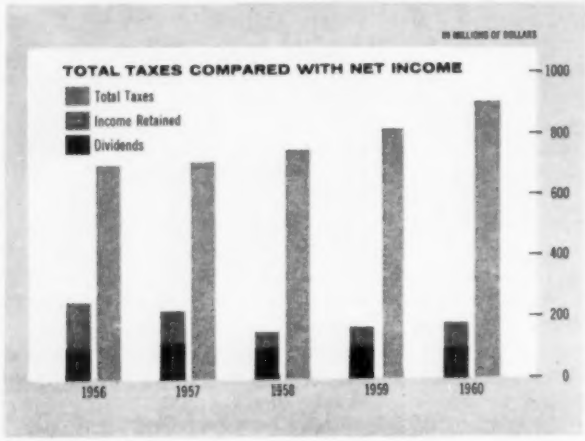
KERR-MCGEE: "Contract drilling activities improved substantially over the preceding fiscal year, due largely to an increasing emphasis on foreign operations and increased drilling activity in the Gulf of Mexico."

The risks showed up, too. Not only

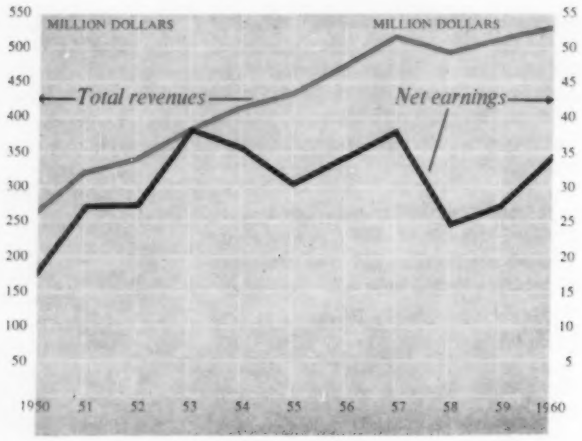
REACHES 75th YEAR

Sun Oil Company is celebrating its 75th anniversary this year at a series of 55 birthday parties for employees and their spouses. Robert G. Dunlop, president, has spoken at eight parties so far and has 47 more to go, finishing the series on October 27 in Sarnia, Ontario.

The company goes back to 1886 when the founder, Joseph Newton Pew, and his partner, E. O. Emerson, began acquiring oil properties in Ohio. Earlier, they had been engaged in piping natural gas from western Pennsylvania fields to Pittsburgh for home and industrial use.



SOCONY MOBIL *gives startling view of governments' profits compared to the company's. On per share basis, stockholders got $2 in 1960, company kept $1.76, government took $18.64.*



UNION OIL OF CALIFORNIA *exhibits lag in earnings in spite of expansion in gross income. In 1953 profit was 9.9% of revenues; in 1958, 5.1%, and last year 6.4%.*

did Cuba confiscate the big refineries, it shut out sales.

QUAKER STATE: "In spite of the loss of valued accounts in Cuba, due to the embargo, new accounts (export sales of lubricants and waxes) were opened in Europe and the Near East, as well as in South America."

A case is made for the domestic company by one of the most stable producing firms.

TEXAS PACIFIC COAL AND OIL: "That the American investing community has a growing awareness of the security of domestic investment as contrasted to others has been made apparent in many ways. Investors have seen companies dependent on imported raw materials forced to curtail capital growth in order to maintain current earnings. Investors have suffered the blows of arbitrary tax increases abroad, contracts notwithstanding, of 'intervention,' and of plain, bold confiscation."

Is research still occupying a prominent place in industries plans?

The industry is faithfully devoting more funds each year to this guide to more useful and more profitable products and methods. It is hard to find a more fascinating subject.

DOUGLAS OIL OF CALIFORNIA developed "Drive-Walk," about which its report said, "In addition to its commercial and industrial uses, 'Drive-Walk' is ideal for do-it-yourself resurfacing or residential driveways, walks and patios."

Among other things ESSO RESEARCH was working on "a durable colored plastic to be used as a surface coating for asphalt paving. Such surfaces would not only be attractive in domestic and commercial use but would provide an additional safety factor on highways and on airport runways."

Reported PHILLIPS: "Studies of an advanced nature were started at Phillips Research Center with a new plasma jet facility. It uses high temperatures, not possible before, to break down matter into ions and other particles. One potential use is the starting of new chemical reactions.

"Research people continued exploratory work on fuel cells, applying broad background in chemical and energy studies. Fuel cells may present a very efficient way to convert hydrocarbon fuels directly into electricity and to synthesize chemicals. They would thus further enhance petroleum's place in respect to other energy sources."

Reflections of national interest came into several research reports.

UNION OIL OF CALIFORNIA's subsidiary, Global Marine Exploration Company, was the one that "received a contract from the National Science Foundation for experimental drilling in 12,000 ft of water. This is the first test step in the Mohole project — an attempt to drill through the earth's crust."

TEXACO, INC: "The Government has contracted with the company to carry out certain research projects in the defense and space fields. These include research on missile and rocket propulsion systems and related problems in the high-energy fuel field."

One effect of political action was that some research was stopped. RICHFIELD reported: "Because of the current moratorium on the testing of nuclear explosives to which Canada, the United States and Russia are some of the parties, it was not possible to proceed with a field test program in 1960 in the Athabasca Bituminous Sands Region of northeastern Alberta, Canada."

What about mergers and acquisitions? Has this trend quieted down?

We don't think of mergers and purchases in the petroleum industry as a trend — which we define as turning in a certain direction. Ownership changes are as natural and needed in the petroleum industry today as they were a decade or two decades ago. Each time one drops from our list because of a merger or sale, we can choose from several new ones coming up.

SIGNAL OIL AND GAS has grown from a net worth of about $9 million in 1945 to $199 million in 1960, largely by mergers.

ANDERSON-PRICHARD sold most of its oil and gas properties to Union Texas and its management organized Apco to buy the company's transportation, refining and marketing.

DELHI-TAYLOR purchased Three States Natural Gas and 35% of Billup and Eastern Petroleum Company.

W. R. GRACE bought 53% of Cosden Petroleum Corporation, which is operated as a subsidiary.

Atlantic Refining purchased Cundiff Petroleum; Colorado Oil and Gas merged with COG Minerals; Gulf bought Wilshire Oil of California; Kerr-McGee purchased People's Service Stations; Ohio Oil bought Kinney-Coastal Oil Company properties and Ross Oil Corporation; Marathon Pipe Line Company (Ohio Oil) acquired remaining 50% interest in Muskegon Pipe Line; Permian Corporation bought

Cactus Petroleum; South Penn bought remaining 50% interest in Bradford Transit Company; Jersey Standard bought Monterey and Rasiom (Italian).

This is not a comprehensive list. We'd say, also, it's about the same size as those of other years.

What is the political outlook? Is there any change in the legislative picture?

The same problems are underfoot and petroleum opponents appear to nibble away at our defense. Some improvements, however, may be on the way. Here are our government problems some of the things annual reports say about them:

CITIES SERVICE: "Congress is considering several resolutions providing for national energy studies. Some of these proposals look toward Federal control over end use of all forms of energy. It is essential that any such studies, or policies resulting therefrom, preserve the principles of free enterprise in the development of America's energy resources, and consumer freedom of choice of fuels."

STANDARD CALIFORNIA: "Debate continues in Congressional circles and elsewhere over the propriety of the percentage depletion provision of the Federal income tax law.

"It is a fundamental principal of income tax law that a taxpayer should not be taxed upon the conversion of capital, but only upon the realization of income. When a producer extracts oil from the ground and sells it, a substantial portion of the proceeds results from conversion of his capital in one form — oil — to capital in another form — cash."

GENERAL CRUDE OIL COMPANY: "In connection with natural gas operations, the Federal Power Commission recently effected an important policy change in regard to the regulation of natural gas producers. This involves the establishment of geographical sales prices that will apply to all producers within given areas. Formerly there were attempts to set prices for each producer. Although this new method has the unsatisfactory elements of dual prices (one for existing contracts and another for new contracts) and price standards that are generally considered to be too low, it appears that this is at least a more practical approach than before. However, most of those who are familiar with this problem are of the opinion that it could be solved by competition if it were not for governmental interference."

CAPITAL AND EXPLORATION OUTLAYS OF U.S. COMPANIES
Here and Abroad
(Millions)

	1960			1961		
	U.S.	Foreign	Total	U.S.	Foreign	Total
Exploration	$1,140	$ 420	$1,560	$1,170	$ 415	$1,585
Production	2,340	750	3,090	2,230	780	3,010
Transportation (not gas transmission)	300	225	525	400	235	635
Manufacturing (including petrochemicals)	765	305	1,070	1,005	420	1,425
Marketing	775	290	1,065	800	305	1,105
Other	110	50	160	110	50	160
TOTAL	$5,430	$2,040	$7,470	$5,715	$2,205	$7,920

MIDWEST OIL: "The natural gas industry continues to carry a heavy burden of unworkable Federal regulation that should be removed by new legislation."

SHAMROCK: "The mounting tax burdens at all levels and the increase of other costs of operations without appropriate increases in product prices continue to be of serious concern to Shamrock as well as the entire industry."

SUN OIL names four primary problems:

1. *Excessive rate of taxation imposed upon gasoline.*
2. *Continued Federal control over the well-head price of natural gas.*
3. *Quota system governing the importation of crude oil and petroleum products into the United States.*
4. *Current effort of foreign governments to cartelize world markets for oil.*

What about capital outlays for 1961?

Our companies show budgets about 6½% higher than 1960. We still find a small increase in 1960 over 1959. In January 1960 we figured this at 2% and this won't be far off.

As usual, the money goes where the profits look better.

Under manufacturing, which includes petrochemicals, we find a strong increase in investment plans. TEXACO says, "Growing importance of the petrochemical field will require that we make substantial investments in many parts of the world." Pipelining facilities will get a little more than the overall rise, which will take care of new gathering systems in U. S. and of big lines in Eastern Hemisphere in which U.S. companies have important interests.

Both exploration and production will get a slightly smaller percentage of the total outlays than in 1960. There are many companies, however, that will not follow that trend, as there were last year. PURE OIL, for instance, devoted 79% of its capital expenditures to exploration and production and reported, "The 1961 budget for capital purposes contemplates $43,000,000 total expenditures, principally directed to oil and gas producing activities."

TIDEWATER in 1960 spent the largest amount for exploration and production in its history, 54.8%.

SOCONY MOBIL's outlays have expanded in chemicals and marketing; have been reduced in refining and producing. Reads the report: "Proposed capital and exploration outlays for 1961 are $350 million. Of this amount, $204 million, or 58%, is to be spent in the United States and Canada; and $146 million, or 42%, elsewhere.

"The purpose of these expenditures

is to increase the return the company can earn on its investments. We are not interested in growth just for its own sake."

Capital for foreign operations alone is set about 8% higher than in 1960.

PAULEY PETROLEUM reveals: "The company expects to make substantial expenditures during its 1961 fiscal year in connection with its drilling program in Mexico and on the Tidelands Leases in California and as a result of its recent entry into the marketing field. Such proposed expenditures will exceed the amount of cash generated internally. The company has anticipated that the excess of expenditures over cash generated internally will be provided for by sale and leaseback of service stations, bank loans and farmouts."

OHIO OIL reminds its shareholders: "Capital requirements for the stepped-up activity in Libya was the primary factor for an increase abroad."

All budgets are set up on a tentative basis and must be accepted as estimates. Some expenditure data in Table 2 do not include non-affiliated or non-consolidated companies. Several say that U. S. and foreign plans are hard to separate — money will go to the new discovery no matter where it is.

CONOCO explains: "The company is fully prepared to increase its capital budget if attractive opportunities arise, either at home or overseas, as the year unfolds. Continuing attention will be directed to capital equipment investments which will reduce operating costs, diversification into profitable activities related to the petroleum business, and commercial development of foreign crude oil discoveries."

Does the future look better? Will earnings continue up?

A company in petroleum must either be optimistic or quit. The industry was built by people with faith — that oil would be discovered by the turning drill, that pipe lines would be needed to move it, that refineries must be modernized for more products — that people would want to buy. But let them tell it:

SUPERIOR OIL reports: "Long range forecasts of increased demands for crude oil and natural gas as energy sources are most encouraging, so much so that Superior is continuing its intensive search for and development of gas and oil reserves. Without such a program the company could not continue its growth and maintain its position in a highly competitive industry."

TXL OIL: "This excess capacity is gradually being absorbed by increased demand. In anticipation of improved market conditions when supply and demand will be more nearly in balance, our current efforts are being directed primarily toward the search for new reserves of oil and gas. The proportion of exploratory wells in our drilling program increased in 1960, and we expect this trend to continue next year."

UNION OIL OF CALIFORNIA: "The year 1960 was a challenging one to the oil industry. Although 1961 may present even greater challenges, we expect the company to achieve continued progress. The operations of all departments of the company are undergoing intensive evaluation to improve operating efficiency and to make maximum use of our personnel and facilities. Possible areas of further diversification are being studied in order to improve our return on invested capital."

GENERAL AMERICAN: "While persistent curtailment of allowables in some of the largest producing states may be expected to continue for some time, long range prospects for the domestic oil and gas producing industry may advisedly be described as encouraging."

ASHLAND OIL indicates cost cutting is in the future, too: "We are giving much attention to the reduction of operating costs in all departments of the Company. Special attention is being given to transportation, which constitutes a substantial part of the total expense of the petroleum industry."

AMERICAN PETROFINA: "Provided proper restraints are exercised by the industry to confine refinery runs and adjust product yields to prevailing demand, a further improvement in earnings can be realized. Management within the industry must, however, exert active leadership to correct the misguided belief that incremental refinery volume will result in additional profits irrespective of market demand."

ATLANTIC REFINING: "To some degree, of course, the industry's progress in the future will depend upon the wisdom which federal and state governments exhibit in the many areas in which public policy affects the industry."

JERSEY STANDARD: "World tensions present problems, but they can also be signs of growth and development. We are in a period when rapid economic improvement is the urgent goal of every nation. The striving of all peoples for social and industrial development is bound to increase the demand for the abundant low-cost energy provided by oil. It will also open up the possibility of markets for entirely new products derived from petroleum. In this developing world we see great opportunities."

In its report to employees in *Shell News*, SHELL OIL sounded a warning on petrochemicals: "The chemical industry, like the oil industry, is plagued with oversupply, tough competition and low prices. Shell Chemical Company sales last year were only slightly more than in 1959. But growth prospects in many chemicals are good, and we fully intend to continue our aggressive expansion."

SINCLAIR OIL: "Throughout human history things have continuously changed, but in our era they are changing at an accelerated rate. There are new opportunities to be secured and new challenges to be met. Your company is keenly alert to these conditions, and 1960 saw many actions designed to meet them to best advantage. Among important accomplishments was a continued strengthening, balancing and streamlining of the management organization at all levels. It obviously is a task which is never completed, but major progress was made."

Boiled down, what is the consensus?

The future for petroleum depends on the larger picture of general economic conditions. It depends also upon specific legislation that affects industry operations. It depends on the weather. It depends on managements' judgment.

Because of 1960, the future has a brighter look.

The industry has reduced or removed wasteful practices.

It has become more flexible, can move into profitable areas more quickly.

It still has its strong bread-and-butter market for crude oil and regular oil products.

It has greater research programs to create new markets.

It has a capital and exploration expenditures budget that should put it in shape for any present demand and for long term growth. ★ ★ ★

1959 SURVEY AVAILABLE

For those who keep the surveys of annual reports we have a few reprints left from last year.

This is the 14th year for this financial analysis. We are grateful to the companies for their help in providing data that allow us to work with more uniform material.

An article on "People in Petroleum" is scheduled for later publication.

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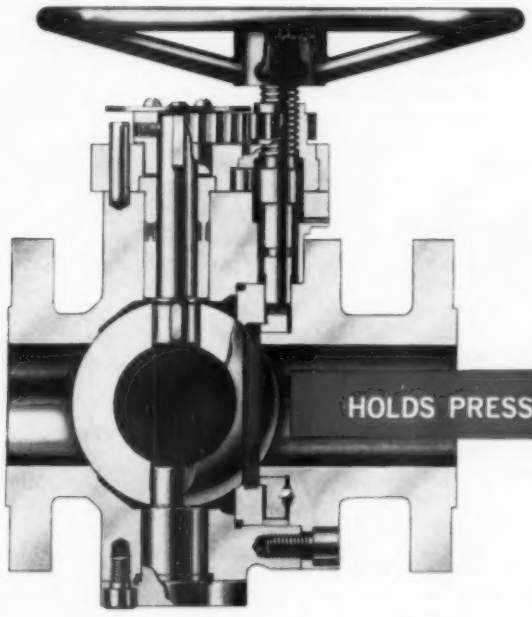

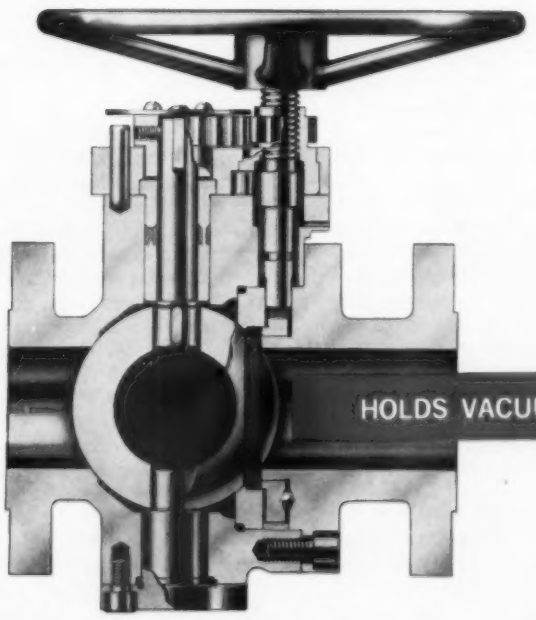

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BOARD CHAIRMAN EXPECTS ACTION—IN SAFETY, TOO!

HONORABLE ROBERT S. KERR

IN 1945, the safety program in our company had not been adequately developed. It was not uncommon in those war days. People were tense, and adequately trained help could not always be found to meet war production needs which were higher than ever before. In this situation with all its circumstances, we knew we needed a safety program at Kerr-McGee, so we hired Sam King as safety director. We told him that it was to be his job to reduce the accident rate as much as possible, thereby (1) preventing the pain and suffering of our people, (2) increasing production, and (3) reducing insurance costs, and in that order.

Within three years our accident frequency rate had been cut 70%. Production increased, and insurance rates had been tremendously reduced. Sam had done a very fine job. On the basis of the phenomenal gains made in safety, the board of directors and I felt real good about the way Sam was progressing. As head of the safety department, safety was Sam's business, the same as engineering problems were the responsibility of our chief engineer.

We, as executives, did not detach ourselves from the administrative problems encountered by our department heads; but we felt that it was our primary job to run the organization, formulate company policy for that organization and give advice and counsel only when necessary. Otherwise, department heads were pretty much left to run their own show. We kept up the insurance premium. But in return for maintaining a more or less hands-off policy, our board of directors and I expected action.

That was the situation in 1948, the first year I served in the United States Senate. During 1948, accidents killed 98,000 Americans. Ten million were injured by accidents.

But in Washington as Oklahoma's junior Senator, I began to lose personal contact with operations of our company. In fact, my work as Senator was a full time job. Then one day I received the news of an automobile accident. In it our drilling superintendent was killed. He was a cousin of mine and a dear personal friend. He had been with the company a long time. His death was not only a tremendous shock to our entire organization, it was a personal loss to most of us as well.

Soon after this I began seriously to dig into gruesome statistics pertaining to national death and injury rates, which were at that time zooming shockingly throughout the nation. The Americans accidentally killed and injured suddenly became a personal matter to me. I now realized action must be taken on a large scale. I now realized that every American must take personal action to destroy and deter this "accident" monster which claims casualties more devastating than any war in which we have ever been engaged.

I realized that our nation could not afford to lose a million lives and injure a hundred million of our citizens every decade. At that ghastly rate, over half of all Americans could count on being killed or injured every 10 years. More than that, I found out that the insurance company did not pay near the total costs of accidents. It paid only a part. It was obvious that, in addition to the tragic personal loss, the economic loss was becoming increasingly unbearable.

When I began to read accident prevention manuals published by the National Safety Council, I though I saw a ray of hope. *These experts said accidents are preventable.* As safety engineers and alert citizens and companies began to put their minds to the problem, prevention began to pay. In four years, 1948 to 1952, the death rate dropped from 98,000 to 94,000. Since 1952 the rate has been reduced even further, to 91,000 last year. During these years accidental injuries also declined. Yet accident prevention gains were even greater than the figures show. Traffic injuries and deaths jumped up and these casualties were the number one fly in the safety ointment.

But our own petroleum industry has pointed the way to prevention. Look at the facts. Accident frequency rate has been reduced from 14+ in 1945 to 7+ in 1959. Think of it — a cut of more than 50% in 15 years. This is excellent progress.

When we took as our premise that all accidents are preventable, we began to take action on that basis — at home, at work and at play. We realized that Sam King was not the only person responsible for safety in our company. Each employee had a part to play. Each American had his place, too.

In our company, Sam has been promoted. Now Buck Martin has his title and responsibility. He must work with other safety engineers in their own companies planning, organizing, promulgating the best safety program for each department of his company. For example, when a hurricane roars toward an offshore drilling unit, the crew must be brought to safety before it hits the rig and the plans must be conceived and rehearsed in advance. Buck Martin must establish safe work procedures for cleaning refinery stills. He must develop safe procedures for making pipeline leak repairs. He must develop safe work procedures for each function in each department and safe work practices for every employee of the company. He must also see to it that each employee is entirely familiar with work practices pertaining to his particular job. The safety engineer has great responsibility, but he cannot compel anyone to work safely. Nor can he compel cooperation; but he can educate and thereby achieve both.

The first-line, immediate supervisor has a responsibility for everything from morale to employee-output. It stands to reason that here is our key man to carry the ball in safety.

Figures show that day after day, 85% of all accidents are caused by "unsafe people acts." Since workers' feelings toward their companies and their jobs are created by such things as

EDITOR'S NOTE: Senator Kerr of Oklahoma, who is also chairman of the board of Kerr-McGee Oil Industries, Inc., gave this talk at 1960 National Safety Congress.

company policies, fair treatment, acceptance by the group and security, and since the supervisor implements all these things, his actions, therefore, are most important. No one individual is more important than the supervisor in shaping morale or controlling the actions of workers. The success of the safety program depends largely upon his attitude toward it. At Kerr-McGee we charge the supervisor with the responsibility of making safety work. We expect continuous effort toward that end.

Of course, we cannot shove all responsibility for accident prevention to the safety engineer and the first-line supervisor. Both must have unstinting support from all supervisors in all other levels of management. All of us are very careful to consider the feelings and morale of the hourly-paid workers, but how many of us give proper consideration to the problems of our first-line supervisors? Of necessity their own supervisors in turn must support and encourage them, and give them adequate assistance to keep work progressing smoothly, and on schedule. This condition must prevail throughout the entire organization from top to bottom. It must range from the first-line supervisor up to the board of directors.

Since the war, tremendous strides have been made in the technological field. Automation and transistor are new words, yet already they have come into common usage. Daily we move closer toward some automation in several industries. Our own petroleum industry is working toward that goal.

From the beginning, we at Kerr-McGee were eager to take advantage of these technological developments so we could remain competitive. We urged our engineering department to speed up these installations. We urged them to create more labor-saving devices to make work-conditions safer and more enjoyable for our own people. We were anxious to eliminate back-breaking drudgery and danger which has always existed in oil fields. We look forward to the time when this will be done. But we expect equal progress to be made in safety. We are confident that it will be.

In spite of gains America has already made in accident prevention, six persons have been killed and 525 injured while I have been standing here before you. Those accidents cost the nation $750,000 or about $100 a second.

Needless, wasteful, costly accidents must be prevented. The tragic personal cost and loss must be stopped.

There is no greater job to be done here in America. And by and large you men here are the ones to do the job. You showed the oil industry that it could be done. Now, you and our industry can *show America!* ★ ★ ★

DECREASING GREASING

Improved lubricants and car construction cuts down on automobile demand . . . Will industrial uses make up for this market loss?

AUTOMOTIVE designers are now working on plans for cars that will need almost no maintenance during their first year of operation. Cars today require less lubrication than even last year's models — two manufacturers claim that their 1961 lines do not require chassis lubrication before 30,000 miles, or perhaps three years. But the problem of changing oil remains, and much expensive research would have to be done before a truly "greaseless" car could be achieved.

A car that could be kept almost maintenance-free for a year is both practical and feasible, however, and several factors contribute to the interest in producing such a car. Motorists would naturally welcome the idea of fewer lubrications, and auto manufacturers, who have long appreciated the sales potential involved, have already introduced many innovations that reduce the amount of lubrication necessary and prolong the period between lubrications. Since 1950, there has been a gradual decline in the number of grease fittings on American cars, and the lubricant manufacturers have, over the past few years, introduced many new greases and oils that are much more efficient than earlier types.

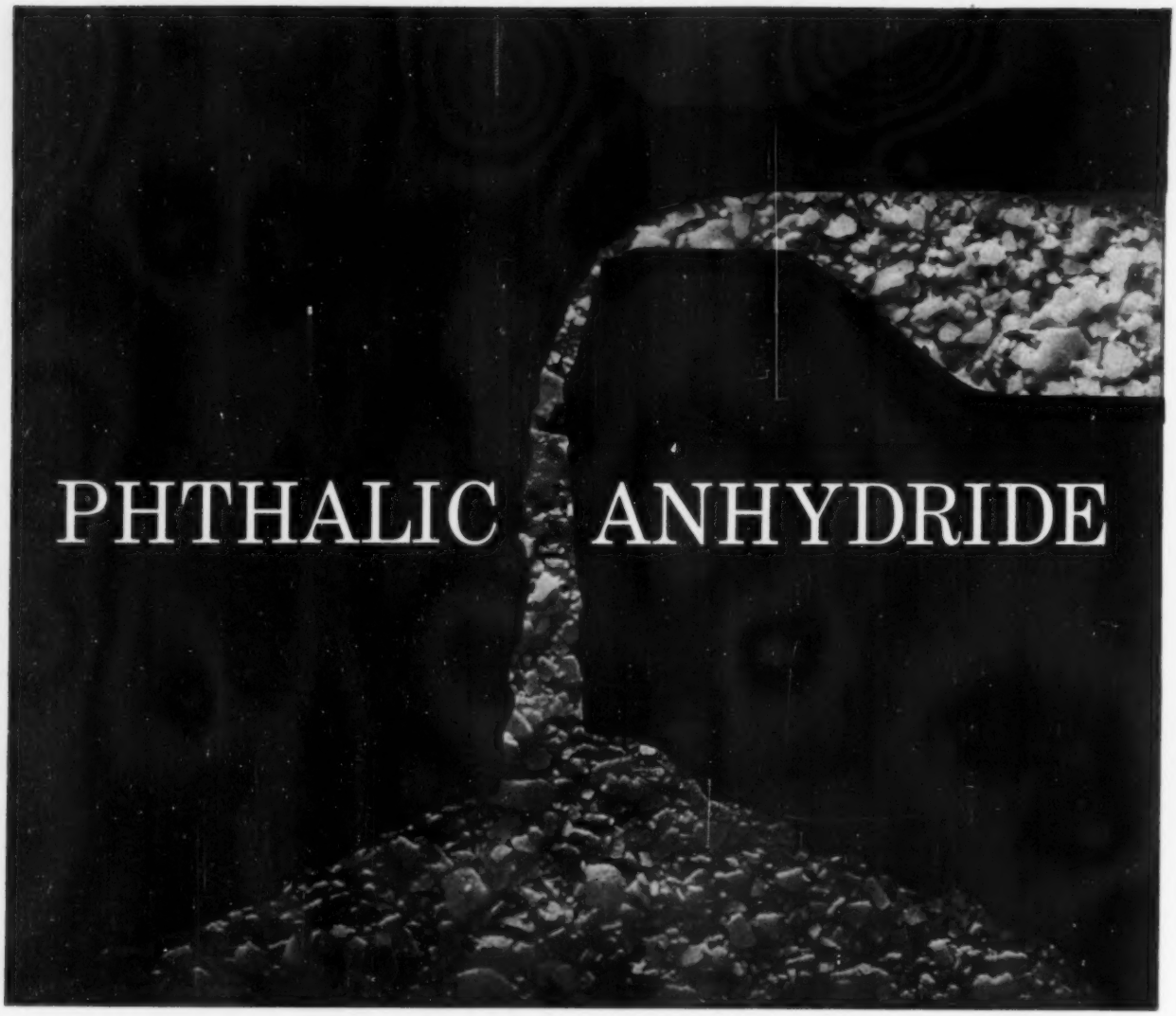
The proper interval between oil changes is still open for discussion. Although motor oils have been improved and the length of time between oil changes extended, the longest interval now recommended by any automobile manufacturer is only 6000 miles. The American Petroleum Institute recommends oil changes every 30 days in winter, and every 60 days in summer, with mileage between changes never to exceed 2000. Thus, while there is an immediate prospect of fewer chassis lubrications, the service stations still have their work cut out for them.

Service station owners will obviously be affected by any drop in consumption of oil and grease; lubrications and motor oil sales account for a sizable portion of their profits. And, if almost maintenance-free cars become common, even the sales of accessory items such as batteries, tires, and mufflers would suffer. As a defensive move, one oil company has launched with its service station owners a campaign for automobile safety inspections, as a means of keeping in frequent touch with customers.

The impact of the shift toward maintenance-free cars will be felt in allied industries as well. Among the oil companies, there has been a great deal of speculation as to whether the increasing number of automobiles on the road will offset the decline in oil and grease consumption per car. A fairly rapid drop in the annual consumption of automotive grease is expected — from about 100 million pounds in 1960 to about 40 million pounds in 1965. The decline began about four years ago, and the trend will become more pronounced as the percentage of new cars increases. The quality of all lubricants is expected to continue to improve, however, and the oil companies expect that part of the loss incurred by any decline in automotive sales will be offset by gains in industrial applications of greases.

Others who might feel the economic effects of reduced automotive lubricant consumption include the manufacturers of cartons, labels and cans; firms that produce grease and oil dispensers (there has been some talk of removing the grease racks from the front areas of service stations); the collectors and users of waste lubricants; and perhaps even the Federal and state governments, which derive some of their income from taxes levied on automotive lubricants and motor oils. All the economic implications are not yet clear, but the trend toward less lubrication is evident. ★ ★ ★

Editor's Note: This article was taken from Industrial Bulletin, published by Arthur D. Little, Inc., Cambridge, Massachusetts, consultants on research, engineering and technical economics.



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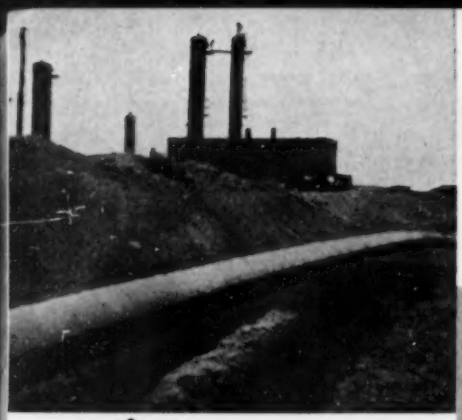

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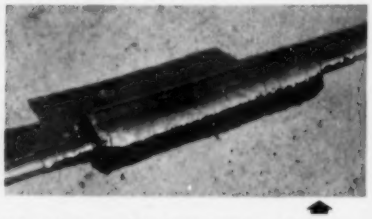

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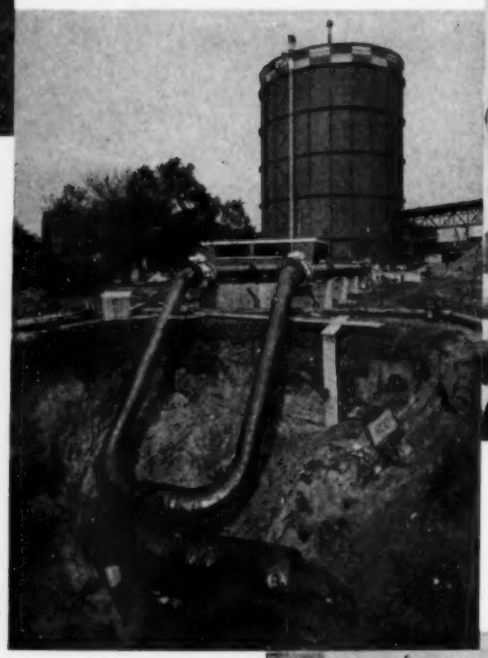

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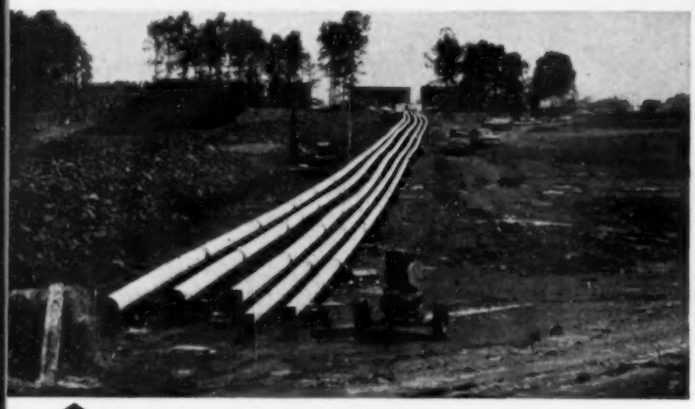

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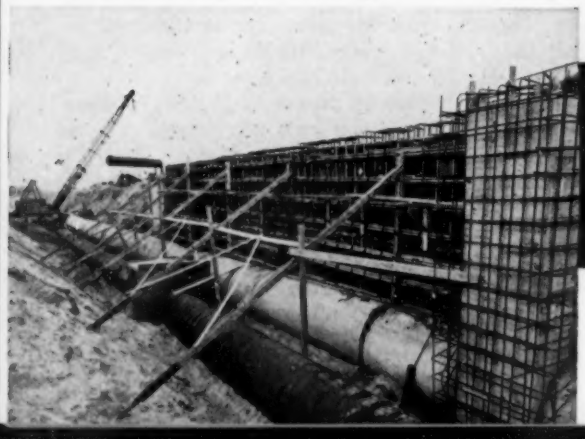

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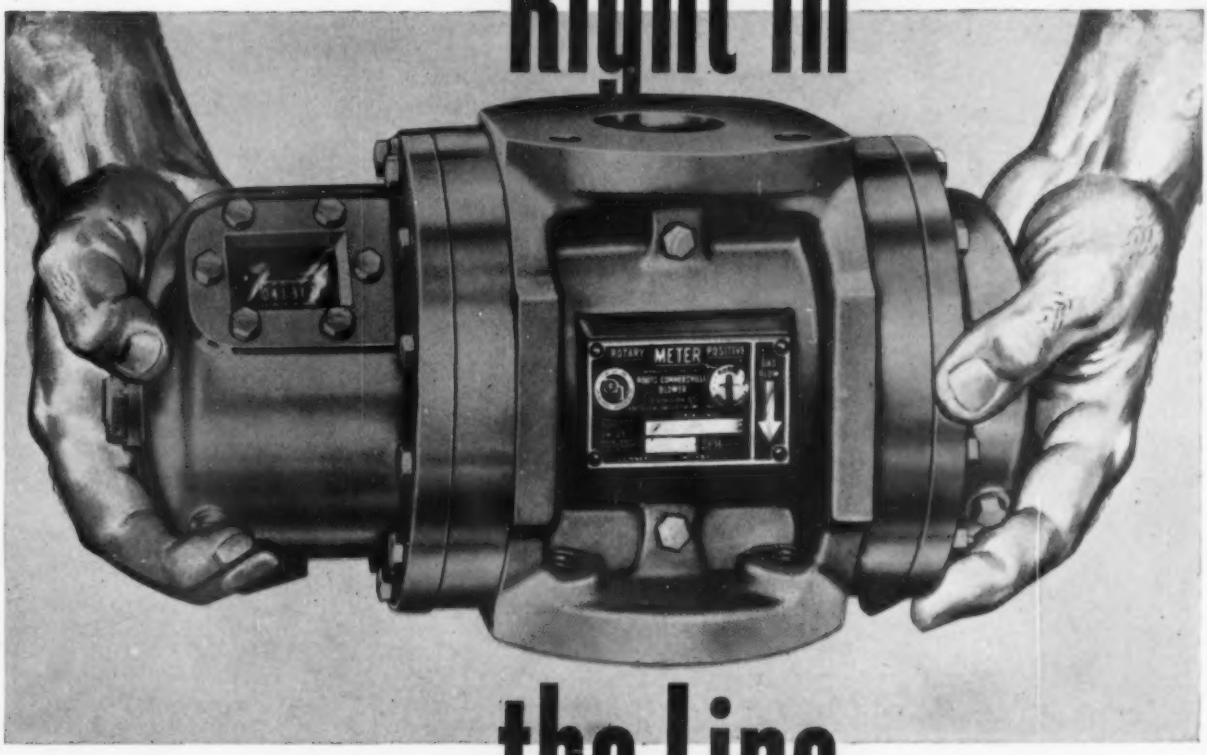

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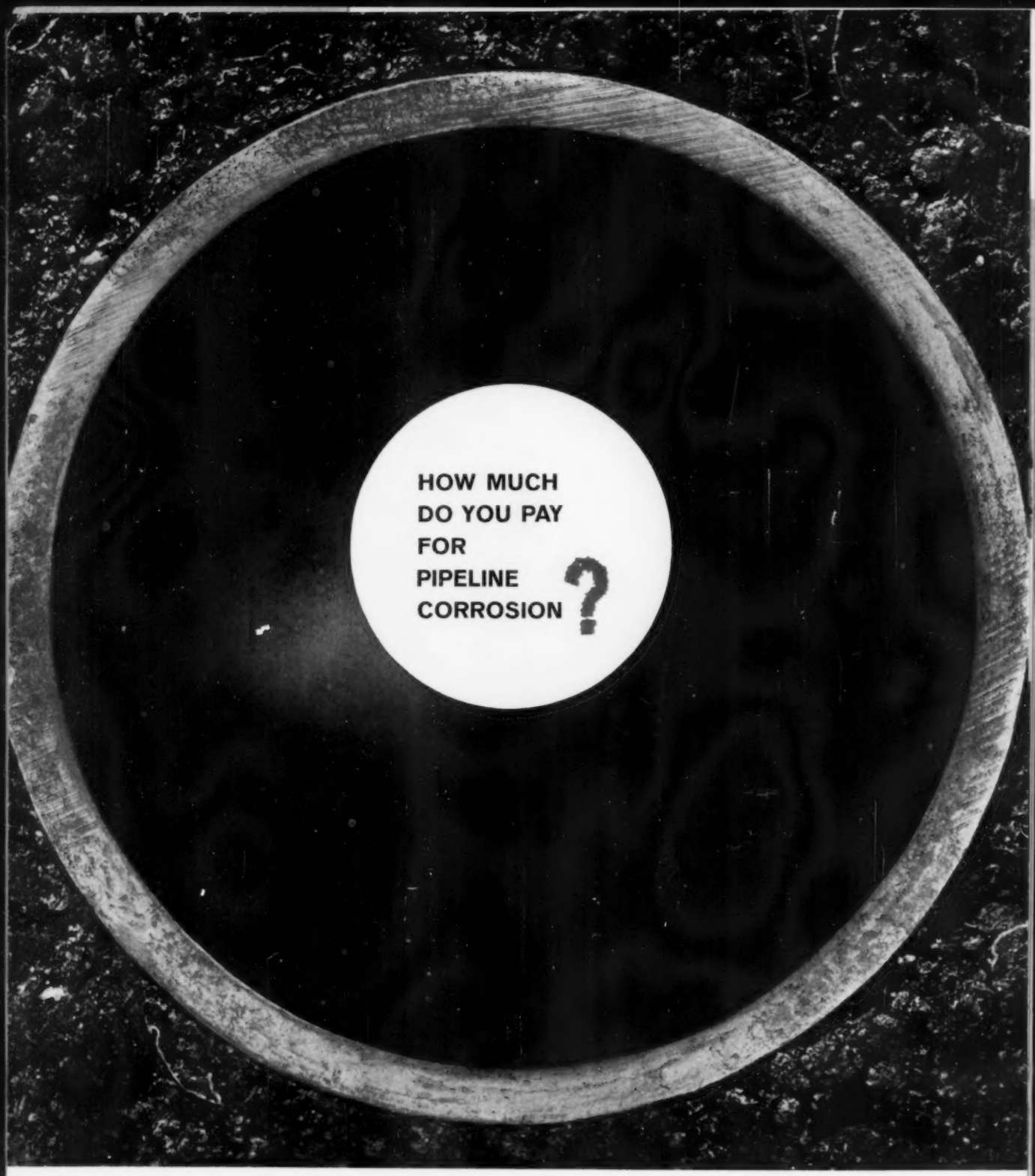

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1. For more information on ***Advertised Products*** or ***Services*** in this issue . . . list the page number of the advertisement and name of the advertiser.
2. For more information on ***New Equipment, Catalogs*** and ***Sales Literature*** reviewed in this issue, circle the code number on the card below corresponding to the code number of the New Equipment or Literature item.
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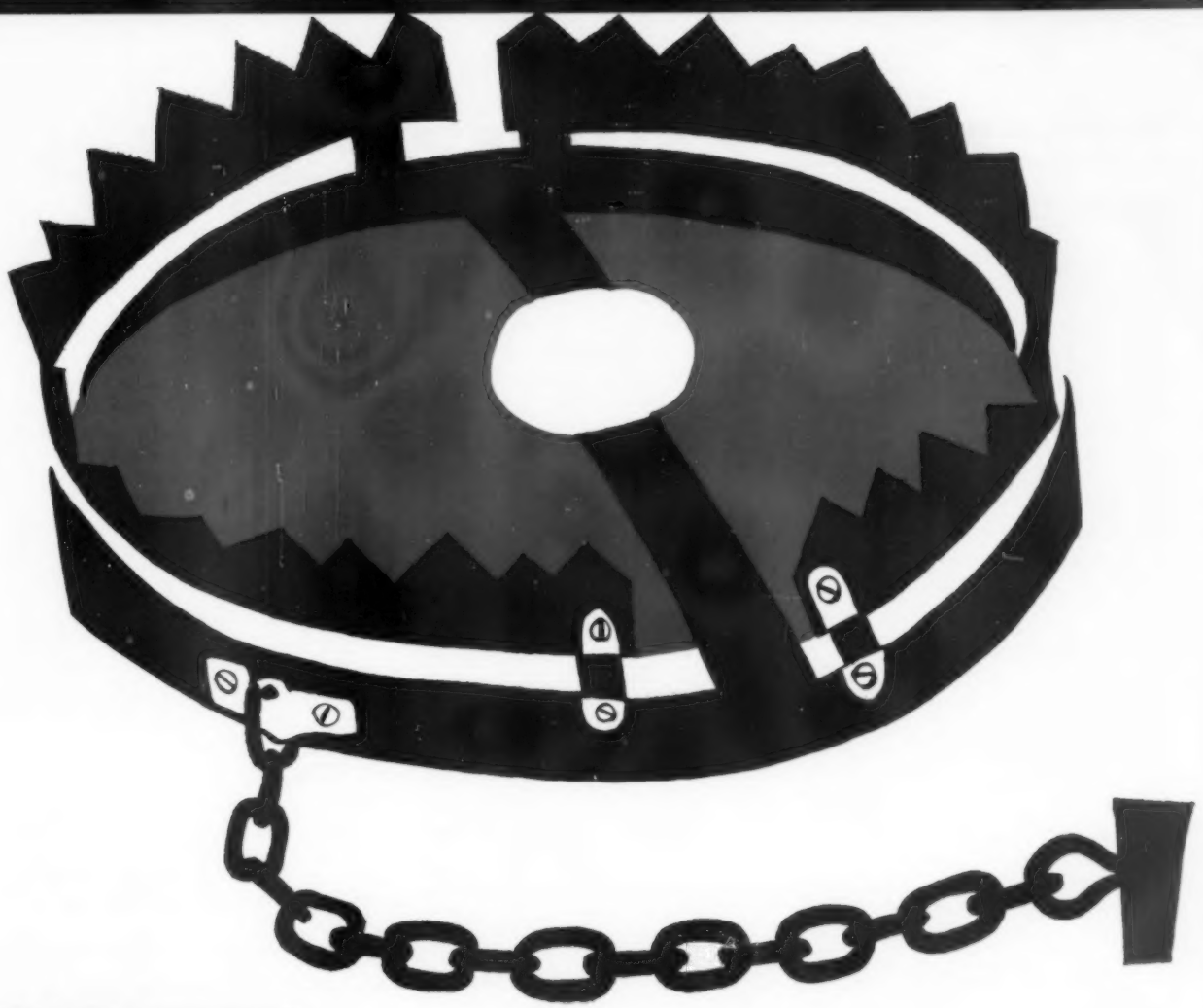

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Management Personals

Dr. P. M. Pitts

▸ **Dr. Paul M. Pitts** was named assistant to the general manager of The Atlantic Refining Company's research and development department. **John C. Martin** is now manager of the general services division of research and development. Dr. Pitts joined Atlantic in 1949 and has held various management positions in the department, most recently serving as research manager. Martin was previously director of the administrative section of the division.

▸ **Wm. Wallace Mein Jr.,** chairman of the board of Bishop Oil Company and its subsidiary, Canadian Bishop Oil, Ltd., resigned both posts in order to devote more time to Calaveras Cement Company, a division of The Flintkote Company. He is a vice president of Flintkote and president of Calaveras. **George E. Lindelof Jr.,** of Los Angeles was elected to the Bishop board and **Lewis Coleman** of San Francisco was named to the board of Canadian Bishop. Resignations of directors, **Louis J. Brunel** and **S. Waldo Coleman,** were accepted.

▸ **H. H. Raborn,** formerly treasurer and assistant secretary, has become vice president and general manager of marketing for Kerr-McGee Oil Industries Inc.

D. A. Watkins, formerly controller, is now treasurer and assistant secretary.

Paul Puttroff, formerly secretary-treasurer of Kermac Nuclear Fuels Corp., moved to Kerr-McGee's general offices as controller.

Refining, crude oil supply and pipeline transportation activities of the company have been made additional responsibilities of **F. C. Love,** executive vice president.

Leo Garwin has been given responsibility for the sale of helium from the company's plant now under construction in the Pinta Dome area of Arizona.

▸ **W. H. Hudson** was named president and general manager of Stekoll Petroleum Corp. He was formerly president of Three States Natural Gas Company.

▸ **E. J. Karle** was appointed vice president of California Oil Company, Eastern division, succeeding **C. E. Allen,** retired.

E. J. Karle

Karle was manager of operations of the refining department and formerly served as an engineer for Standard of California, at its Richmond, Calif., refinery prior to his transfer to the East Coast. Karle also assumes the duties of general manager of the refining department. Allen also began in the engineering department of Standard of California. After working in the company's three California refineries, he was transferred to the California Refining Company at Perth Amboy and named president and director in 1948. When the company merged with California Oil Company in 1952, he became head of its refining division.

▸ **Rayburn L. Foster,** vice president and general counsel of Phillips Petroleum Company, and a director and executive committee member, has retired. **William J. Zeman,** presently general attorney for the firm, succeeds Foster.

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▸ **Don W. Conaway** was appointed manager of oil and gas sales and purchases for the British-American Oil Producing Co., with headquarters in Dallas, Texas. In his new position, Conaway will negotiate sales contracts for natural gas and liquefiable petroleum gases, approve the company's investments in processing facilities, and supervise the purchase of all oil and condensate by the company's subsidiary, the Toronto Pipe Line Company. He succeeded **Myron Messner,** retired.

▸ **Robert H. Colley,** former president and chairman of the board of The Atlantic Refining Company, and a director of the firm since 1954, has retired after 42 years service. He joined Atlantic in 1919 as an asphalt salesman after serving overseas in World War I. A year later, he was made treasurer of another oil company in Lexington, Kentucky, in which Atlantic owned a large interest. With this experience, he returned to Philadelphia in 1926 as assistant treasurer of Atlantic and, in 1929, was elected treasurer and a director. In 1937, he was elected president of the company and held this position for the next 15 years, leading the company through the post-depression build-up, the difficult years of World War II, and the rapidly expanding economy that followed. In 1952, he became chairman of the board. Two years later, he retired from this top post but continued as a director.

R. H. Colley

▸ **Harold C. Gutjahr** was made comptroller of Consolidated Oil and Gas, Inc., Denver, Colorado. He was formerly associated with W. L. Clasquin (CPA's). **William C. McVinua** was named chief accountant. He was formerly with King-Stevenson Oil Company.

▸ **Blanche Kelley,** lady veteran of the oil business, was appointed to help plan the 19th National WAVES Reunion. She was secretary to the vice president in charge of foreign and domestic exploration of Union Oil of California, who is now retired and a petroleum consultant.

▸ **A. E. Stebbings** was named a vice president of Signal Oil and Gas Company. He is also general manager of the marketing department, a post he has held since 1958.

QUIET!

New Lonergan liquid relief valve doesn't chatter; eliminates product waste; reduces maintenance

Ever hear a relief valve chatter? They all do! They shout their faults to the world, while beating themselves to death. When you can hear one, you know product is being wasted; maintenance costs are increasing; employees are growing annoyed; and perhaps dangerous, flammable liquids are running loose.

Now you can install a Lonergan Hydro-Valve guaranteed not to chatter, hammer, or drum, *yet still deliver full rated capacity !* Gone is the need to install an oversized valve or a high-priced, heavyweight regulator valve to eliminate chatter on by-pass and emergency relief applications.

The Lonergan Hydro-Valve does not contain any capacity-reducing gimmicks or gadgets to eliminate chatter. Instead, it is designed to be completely quiet under all operating conditions. It proves itself so on hundreds of applications every day.

Bellows models of the Lonergan Hydro-Valve are also available for corrosive applications. The elimination of chatter and its associated bellows flexing action, greatly extends bellows life and virtually ends the need for expensive bellows replacement. *Full details are in a Hydro-Valve bulletin. Write for a copy today !*

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FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

▸ **D. H. Barran,** president of Asiatic Petroleum and Shell Caribbean Petroleum, has been appointed to the board of The "Shell" Transport and Trading Co., Ltd. He suceeds **F. J. Stephens** as managing director of the Royal Dutch/Shell Group effective July 1. Stephens will succeed **Lord Godber,** retired. **H. Wilkinson,** C.M.G., a group managing director, has been appointed a managing director.

▸ **Millard E. Stone,** vice president in charge of employee and community relations for Sinclair Oil Corporation, has been named to the Committee on Public Affairs of the American Petroleum Institute. He succeeds **Joseph P. Walsh,** general counsel for Sinclair, as a member of the committee.

▸ **Donald A. Hamilton,** recently transferred to the gas company in Oklahoma City from Arkansas Fuel Oil Corporation, is newly-elected assitant treasurer of Cities Service Gas Company.

▸ **Judson Laird** was named manager of newly created community services division of Sun Oil Company's public relations department. More recently he has specialized on the public relations aspects of gasoline taxes and highway problems.

SAVED! 16,000 Lbs. in total truck weight! SAVED! 25% on initial price! Thanks to the rigid demands of Producers Chemical and the ingenuity of **FRANK WHEATLEY'S** engineers, this quintuplex, non-surging plunger pump is now available at a savings of 25% over competitive units. For fracturing, cementing, salt-water disposal and water flooding—talk to your **FRANK WHEATLEY** representative about the pump that only weighs 10 lbs. per horsepower . . . The **FRANK WHEATLEY** Series 400. **Series 400 features: 10,000 PSI MAX. • 8,500 BPD • 75,000# PLUNGER LOAD • 6 PLUNGER SIZES AVAILABLE. • CAN BE TWIN-MOUNTED BACK-TO-BACK. • AVAILABLE IN TRIPLEX MODEL.** The biggest reason **FRANK WHEATLEY** is "number one" in plunger pump sales is not only "completeness-of-line" but EFFICIENT FIELD SERVICE! A team of twenty men is ready day and night!

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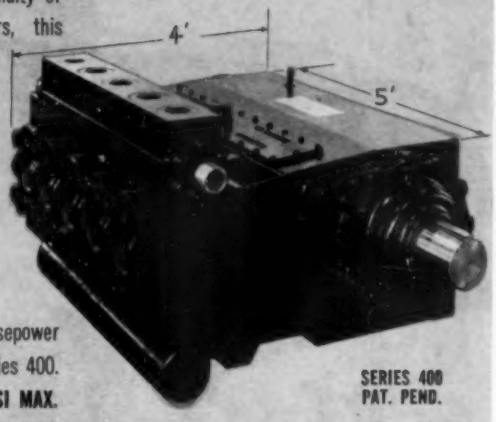

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challenge!

a 5-cylinder pump-4" stroke-4' long x 5' wide-5000# wt.-500 hp.-600 rpm

they said it couldn't be done!

Then They came to Frank Wheatley

▸ **Dr. Valliant C. Baird** was made medical director of Humble Oil & Refining Company, principal operating affiliate of Standard Oil Company (N.J.). He has been chief physician of the company's Humble Division, and now is responsible for coordination of all medical activities of the company.

▸ **William B. Bateman** has been appointed vice president of The Chase Manhattan Bank, in the United States department. He is in the petroleum division. Joining the bank in 1947, he was appointed an assistant treasurer in 1950 and was advanced to assistant vice president in 1953.

▸ **Charles H. Sommer,** president of Monsanto Chemical Co., has been elected a director of Chemstrand Corp. Monsanto recently acquired 50% interest in Chemstrand.

▸ **John DeSisto,** head of Mene Grande Oil Co.'s special studies section in the Caracas exploration department, has been elected president of Asociacion Venezolana de Geologia Mineria y Petroleo. He served as advisor on the board of AVGMP during the 1960-61 term.

▸ **Abdulaziz Wattare,** acting director general of oil affairs in the Irag Oil Ministry, has been named director general.

▸ **W. F. (Bill) Hand,** vice president of Gibson Petroleum Co. in Calgary, has joined Empire Petroleum Co. in Denver as vice president in charge of marketing.

DEATHS

H. A. Ruysser, Jr.

▸ **Henry A. Ruysser, Jr.,** executive vice president of Black, Sivalls & Bryson, Inc., Kansas City, Mo., died March 29. Well known throughout petroleum circles, Ruysser joined BS&B in 1946 as a vice president and board member. Active in civic and youth groups, he was also a member of several business organizations including Petroleum Equipment Suppliers Association.

▸ **Edward S. Plank,** 60, Houston employee of Tennessee Gas Transmission Company, died March 20 in Lafayette, Louisiana, while on a business trip. He was superintendent of the gas measurement department of Tennessee Gas Pipeline Company.

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All give smooth, close regulation and positive shut-off from a few pounds pressure up to high pressures.

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All have deep inlet and outlet threads for tight make-up.

All have special, long-lasting, readily-replaced, special "Marpak" packing incorporating all-but-indestructible Teflon in the stainless steel series.

You see a globe valve representing each series here. Note that the color of the handle identifies the series. Valves come to you individually sealed in strong, transparent plastic packages. In appearance, in operation, in service life you have in these valves the kind of product that only Marsh experience in *both* valve making *and* instrument making could produce.

Globe and angle valves in all three series are available with double female connections in sizes ⅛", ¼", ⅜", ½", ¾" and 1"—with male inlet and female outlet in sizes ¼" and ½". Panel mounted types in all sizes. Write for bulletins.

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TRANSCO 10TH ANNIVERSARY

TRANSCONTINENTAL GAS PIPE LINE CORPORATION

MEETINGS

May 10-12 — **ASME, production engineering** conference, Royal York Hotel, Toronto, Ca.

May 10-12 — **CIM-AIME,** oil and gas division, 12th annual, MacDonald Hotel, Edmonton, Alberta, Can.

May 11-12 — **API Division of Production,** Pacific Coast District, Biltmore Hotel, Los Angeles, Calif.

May 11-12 — **Thirteenth Oil Recovery Conference and Dedication of W. T. Doherty Petroleum Engineering Building,** A. & M. College of Texas, College Station, Tex.

May 14-16 — **Kansas Independent Oil & Gas Assn.,** annual, Broadview Hotel, Wichita.

May 14-16 — **TIPRO's 15th annual,** Scharbauer Hotel, Midland, Tex.

May 17-18 — **Western Petroleum Refiners Assn.,** Mid-Continent regional technical-industrial relations meeting, Hotel Lassen, Wichita, Kans.

May 17-19 — **Society of Professional Well Log Analysts Second Annual and Logging Symposium,** Sheraton-Dallas Hotel, Dallas, Tex.

May 19 — **NGAA,** Permian Basin regional meet, Lincoln Hotel, Odessa, Tex.

May 19 — **Western Petroleum Refiners Assn.,** regional fire and accident prevention meeting, Hotel Lassen, Wichita, Kan.

May 21-24 — **API Division of Transportation,** midyear highway conference, Bellevue Stratford Hotel, Philadelphia, Pa.

May 22-24 — **ISA, AIEE, ARS, IAS, IRE,** 10th national telemetering conference, Chicago, Ill.

May 22-25 — **ASME,** design engineering conference & show, Cobo Hall, Detroit, Mich.

May 24-25 — **Western Petroleum Refiners Assn.,** refiners computer conference, The Benjamin Franklin Hotel, Philadelphia, Pa.

May 25-26 — **Society of Petroleum Engineers of AIME,** Rocky Mountain Sections, 7th annual, Elks Club Building, Farmington, N.M.

May 25-26 — **American Gas Association Transmission Conference,** Denver, Colo.

June 1-2 — **Kentucky Oil and Gas Assn.,** annual, Phoenix Hotel, Lexington, Ken.

June 1-3 — **Interstate Oil Compact Commission,** midyear, Shamrock Hilton Hotel, Houston, Tex.

June 5-8 — **ISA** summer instrument-automation conference and exhibit, Royal York Hotel and Queen Elizabeth Hall, Toronto, Ontario, Can.

June 6-8 — **Appalachian Corrosion Short Course,** West Virginia University, School of Mines, Morgantown, West Virginia.

June 7-9 — **API Division of Transportation,** communication committee meeting, Statler Hotel, Washington, D.C.

June 7-9 — **API Division of Finance and Accounting,** midyear, Jung Hotel, New Orleans, La.

June 9-17 — **ACHEMA,** 13th international chemical engineering exposition and congress, Frankfurt am Main, Germany.

June 11-15 — **ASME,** summer annual, Statler-Hilton, Los Angeles.

June 11-16 — **API Division of Production,** midyear committee conference, St. Francis Hotel, San Francisco, Calif.

June 12-14 — **API Division of Transportation,** annual tanker conference, Oyster Harbors Club, Cape Cod, Mass.

June 12-23 — **Oil Hydraulics Industry,** special summer course for members, Illinois Institute of Technology, Chicago, Ill.

June 13-16 — **ISA,** 3rd biennial international gas chromatography symposium, Kellogg Center, MSU, East Lansing, Mich.

June 14-16 — **ASME,** applied mechanics conference, Illinois Institute of Technology, Chicago.

June 19-21 — **Interstate Oil Compact Commission,** midyear, Shamrock Hilton Hotel, Houston, Texas.

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Laugh with Barney

Then there was the politician who kissed so many hands he had dishpan lips.

* * *

If you want to know how your girl will treat you after you're married, just listen to her talking to her little brother.

* * *

Old maid to robber: "Oh, gracious, frisk me again."

* * *

The shipyard worker was trying to teach a new lady riveter what to do.

"I'll hold the rivet," he said "and when I nod my head, you hit it with the hammer."

She did.

He left a widow and three children.

* * *

An English lady, self-appointed supervisor of village morals, accused a workman of having reverted to drink because "with her own eyes she had seen his wheelbarrow standing outside a tavern.

The accused made no defense, but that evening he put his wheelbarrow outside her house and left it there all night.

* * *

A change of lipstick now and then is relished by the best of men.

* * *

The judge listened intently to a case against a man who was charged by his wife with non-support. After all the evidence was in the judge told the defendant, "You haven't taken proper care of this good woman and I'm going to give her $25 a month."

The defendant beamed with pleasure. "That's mighty nice of you, your honor," he said. 'And I'll give her a dollar or two from time to time myself."

* * *

"I know we are traveling faster than sound," the passenger said, "because the stewardess slapped me before I got a word out of my mouth."

* * *

The only type of holdup that never lacks witnesses is a strapless evening gown.

* * *

A woman walked into a psychiatrist's office leading a small white duck by a chain.

"What can I do for you, Madam?" the psychiatrist asked.

"Oh: it's not me," said the woman, it's my husband. He thinks he's a duck."

* * *

The pretty young bank secretary finally got married and for the first time found herself on the operating end of a checkbook. Her husband had left her the financial details of homekeeping. At the end of the month he asked her what she had done with all the bills they received.

"Just what we did at the bank," she replied. "I marked them all insufficient funds and sent them back."

* * *

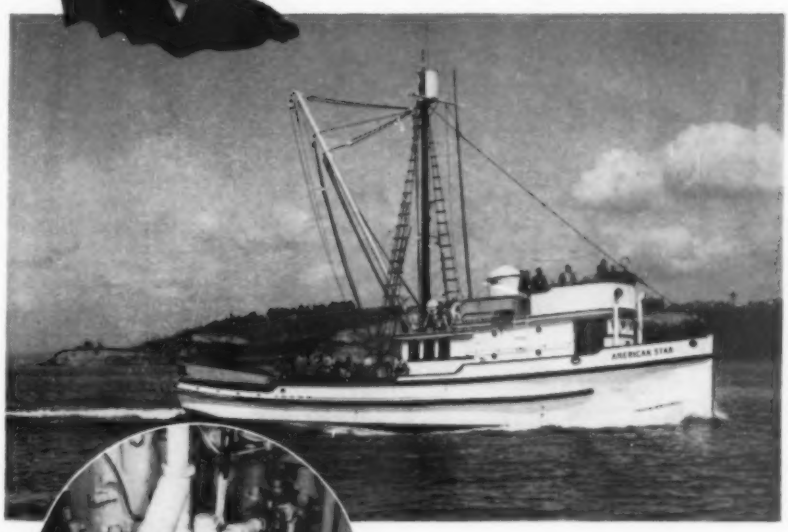
We are told that creatures of the wild are born with a natural spirit of cooperation. This is particularly true of the wolf and the stork, who usually work the same neighborhood.

* * *

"How did you find the ladies at the dance?"

"Oh, I just opened the door marked 'Ladies' and sure enough, there they were."

"the AIR STARTER has never failed us in two years of fishing!"



The "American Star" is a 70' Pacific Coast type herring and sardine seiner. It is powered with a 335 hp Waukesha Defender Diesel. Note compact installation of the Ingersoll-Rand Size 20BM Air Starter.

Captain Edwin Hausen began his fishing career in 1928. He is held in high regard by his fellow skippers and the fishing trade. Here's what he says about air starters . . .

"I do not pretend to be an authority on such equipment. I simply judge the air starter by the way it does its job. We have used the Ingersoll-Rand Air Starter for two years and it has never failed us!

"The American Star's engine is not a small power plant, for its displacement is 2,894 cubic inches. The Ingersoll-Rand Size 20BM Air Starter is about as positive a system as you can find. What's more, it's simple in operation, compact in design and reliable."

Ingersoll-Rand Air Starters are made in 4 sizes for engines from 300 cu. in. to 20,000 cu. in. displacement. For complete information on these highly efficient starters, write for your copy of "Go Modern—Start with Air," Form 5094E.

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YOU know Willy Lumpjaw. He is the antagonist-big-mouth who is out to scuttle your safety program just to prove how smart and tough he is.

Suggest an improvement in job procedure and Willy loudly asserts that it's all a plot to make more money for the company. Discuss an accident and Willy stands ready to prove that it was caused by the foreman's stupidity.

You are trying whole-heartedly to improve the safety and welfare of your men. But do you get appreciation or respect? Not from Willy. Willy Lumpjaw doesn't like supervisors. Do you like Willy? Not very damn much.

But take another look at the guy. Maybe Willy is the best friend you've got.

You are trying to be a good supervisor. You are teaching yourself to approach the problems of your group with intelligence, understanding, patience, dignity, and good humor. And who, I ask, gives you every opportunity to practice and display all those virtues in front of your entire group? Who but good old Willy Lumpjaw, the man with the cast-iron mouth?

So let Willy have his say. And then, when he is through, it is your turn to talk. Keep your temper, keep your perspective, and above all keep your dignity. Be reasonable in the face of Willy's unreasonableness. Be fair even when he is most unfair. Willy will find his work-mates solidly united behind you!

Maybe Willy will learn at last to take a more reasonable attitude. Maybe not.

But in the meantime Willy Lumpjaw is your buddy, your helper, and your stooge.

(This material was written by David J. Doran, assistant safety supervisor, Phelps Dodge Corp., Ajo, Arizona. It appeared in a recent issue of Industrial Supervisor, a publication of the National Safety Council, Chicago. ★ ★

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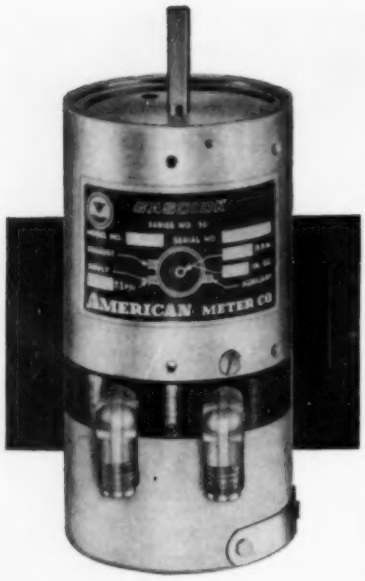

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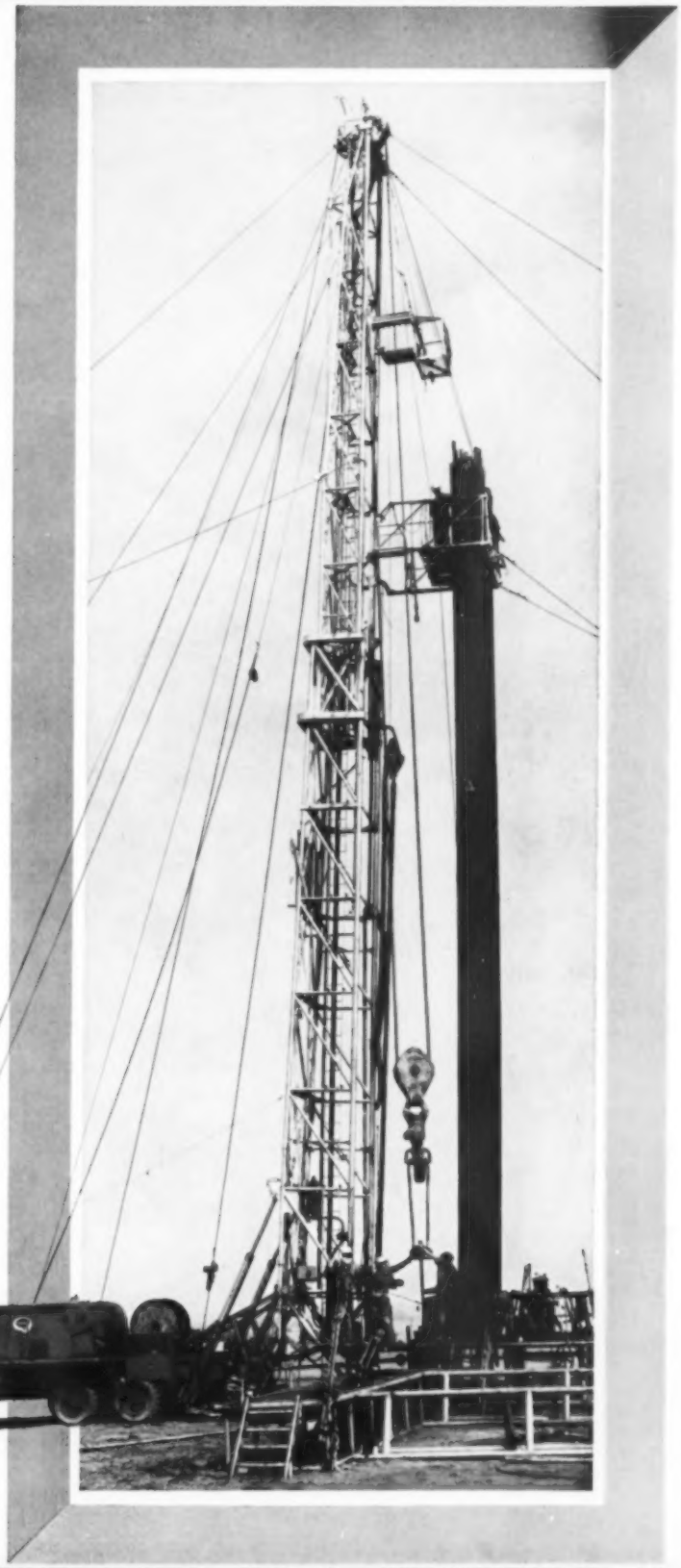

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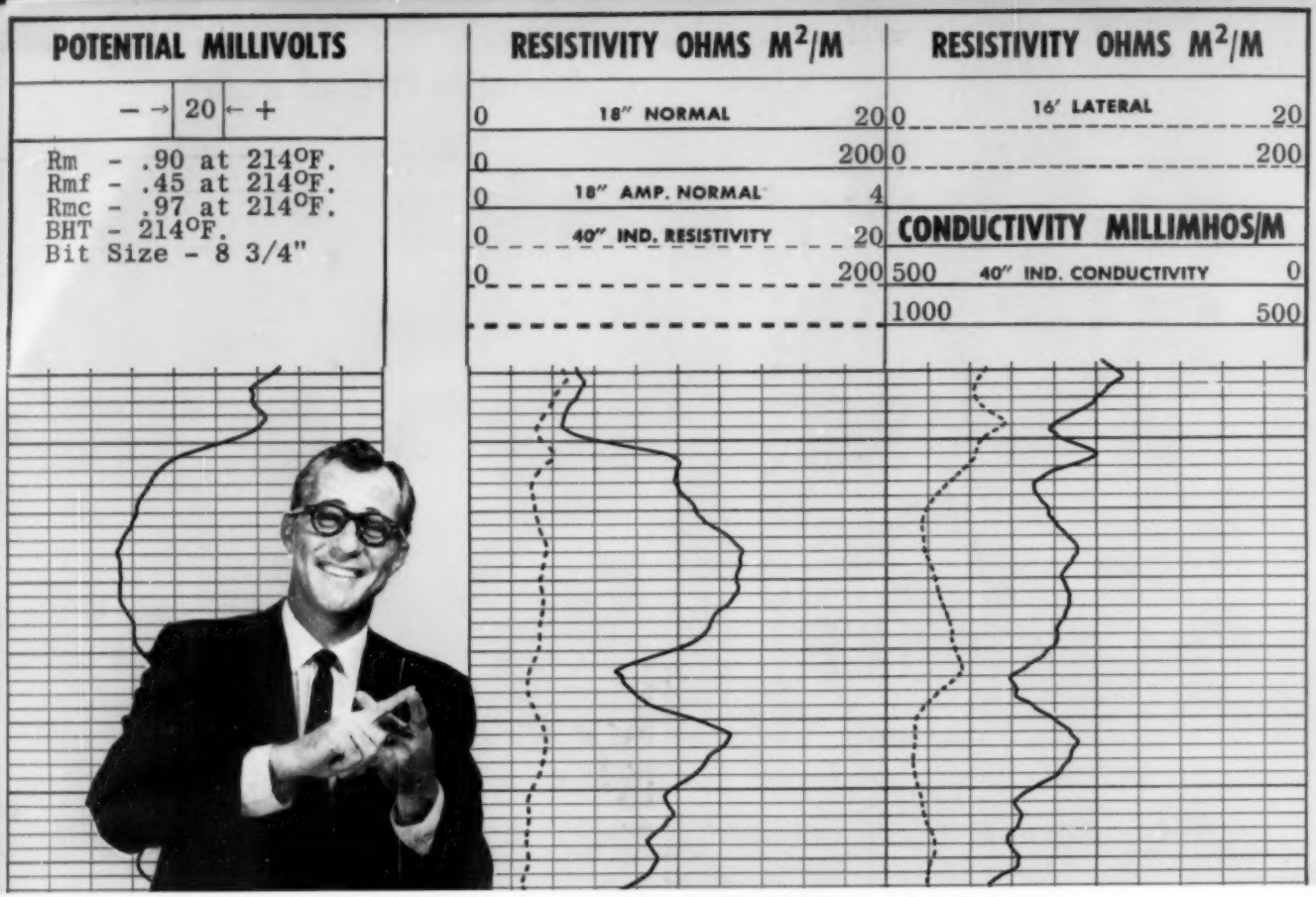

Welex Induction Log With LONG LATERAL Pinpoints Rt, Thin Zones Where Others Fail

A couple of points to remember about using an induction log to determine Rt:

1. Under certain invasion conditions and diameters, an induction curve does not read Rt directly.

2. An induction curve also often overlooks thin (4′ or less) resistive zones bounded by conductive zones.

Now addition of the Long Lateral curve to the Welex Induction-Electric Log solves both problems simply and accurately.

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The problems of deep invasion on short-spaced curves became apparent early in the evolution of well logging.

Even with today's advanced tools this same problem of invasion continued to exist — until the introduction of the Long Lateral curve to the Welex Induction-Electric Log.

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This is the COMPLETE Induction-Electric Log, and when run with one of Welex's porosity logs, interpretation using Welex's simplified charts or "pigtails" is easy, quick and accurate.

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Of Things To Come . . . In Oil

CHEAPER OVERALL WELL COSTS COMING as result of closer cooperation between drilling contractor and operator. Bob Parker, president of Parker Drilling Company, Tulsa, Oklahoma, commented at recent Southwest District API meeting at Albuquerque, N. M., that more and more producers are relaxing deviation clauses, offering multi-well jobs, standardizing blowout preventer hookups, recognizing financial burdens placed on contractors, and looking not for cheapest cost per foot but least cost per well.

LOOK FOR WIDER USE OF SMALL GAS TURBINES as a combination power-compressor package. AiResearch of Phoenix, Arizona, recently signed agreement with Mission Manufacturing of Houston to handle oil field application and sales of its small (30 to 300 hp) turbines. Field tests are to get underway soon to study this power package combination with Mission's hammer drill for air/gas drilling.

EQUIPMENT LEASING, CONTRACT MANAGEMENT GROWING everywhere you look. Maximum use of capital and tax reporting regulations favor both. You can lease anything from a rotary table to a complete tank battery. Contract management firms offer all functions of a good-size operating company to a number of individual lease owners at a nominal cost to each. They provide experienced management, electronic accounting, latest technology and full operating personnel.

A 400,000-BBL DAILY REDUCTION IN MARKET for domestic crude oil in the second quarter may occur with normal seasonal drop in oil consumption, predicts Independent Petroleum Association of America. However, inventories are expected to increase, due in part to March crude production of about 7,350,000 bbl daily, highest monthly rate since the Suez crisis in early 1957.

LITTLE HOPE FOR FEDERAL GASOLINE TAX REDUCTION is held by most industry observers. President Kennedy has proposed extending the "temporary" four-cent rate indefinitely past the original June 30 deadline, and has called for higher taxes on diesel fuel. Petroleum industry leaders and associations will continue efforts to have tax reduced to previous three-cent level.

SHORTAGE OF PETROLEUM ENGINEERS is being forecast by educators. University of Texas has reported decline in number of graduates from 800 in 1957 to 400 in 1960. Overall, U. S. Office of Education reports fourth consecutive year of freshman enrollment decline. Number of graduate students is increasing, however.

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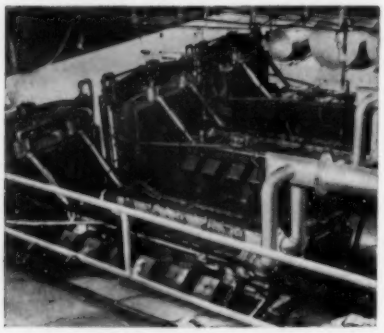

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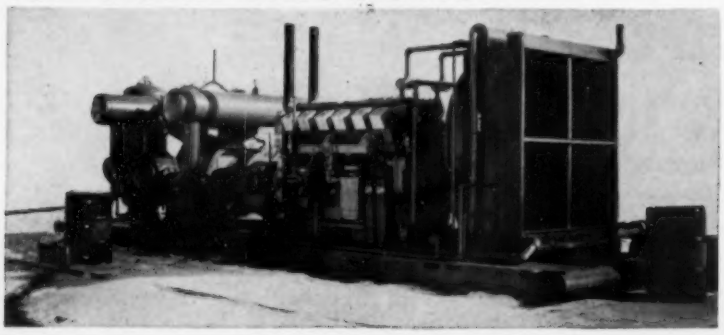
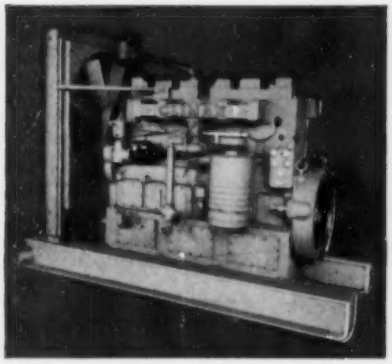
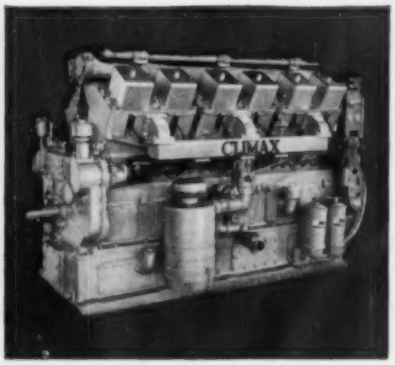
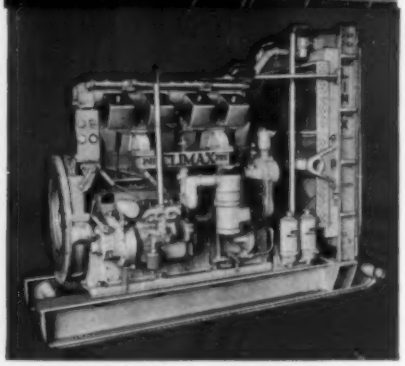




Model K-67—Max. hp 265 (Natural Gas)



Model V-125—Max. hp 605 (Natural Gas)



Model V-85—Max. hp 390 (Natural Gas)

CL-116

CONT. DUTY (NAT. GAS) →			DRILLING-PUMPING (80% RATINGS)						COMPRESSORS (65% RATINGS)				
Model	Bore & Stroke	Displ.	Peak Torque @ RPM	Brake hp at Speeds Indicated					Peak Torque @ RPM	Brake hp at Speeds Indicated			
				600	800	900	1000	1100		800	900	1000	1030
R-165	6⅛ x 7	1238	684 @ 750	81	105	117	127	135	557 @ 800	85	95	103	105
K-67	7 x 7	1616	955 @ 850	110	145	161	176	188	775 @ 800	118	131	143	146
K-75	7½ x 7	1855	1090 @ 800	126	166	185	204	218	885 @ 800	135	151	166	169
V-80	7 x 7	2155	1240 @ 850	140	188	210	230	246	1002 @ 800	153	171	187	190
V-85	7½ x 7	2474	1460 @ 800	164	223	246	266	284	1185 @ 800	181	200	216	221
V-122	7 x 7	3232	1920 @ 800	217	293	328	353	378	1562 @ 800	238	265	288	293
V-125	7½ x 7	3711	2240 @ 850	242	340	384	417	442	1820 @ 900	276	312	340	346

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STANDARD GROVE G-2
Right-now shipment of standard series G-2 valves. Available in either flanged or screwed end. Sizes: 1½" through 4". Working pressure: 1000, 2000, 3000 and 5000 pounds.

Write for Bulletin #581

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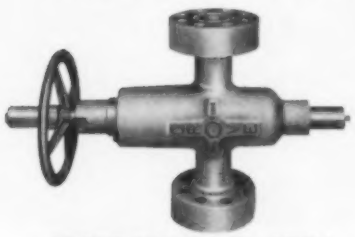
Available in 2" — 5000 #W.O.G.



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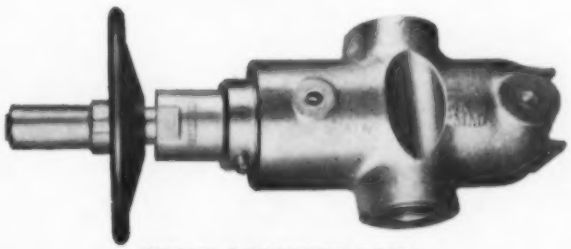

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Available in 1½" and 2" — 2000, 3000 and 5000 #W.O.G.

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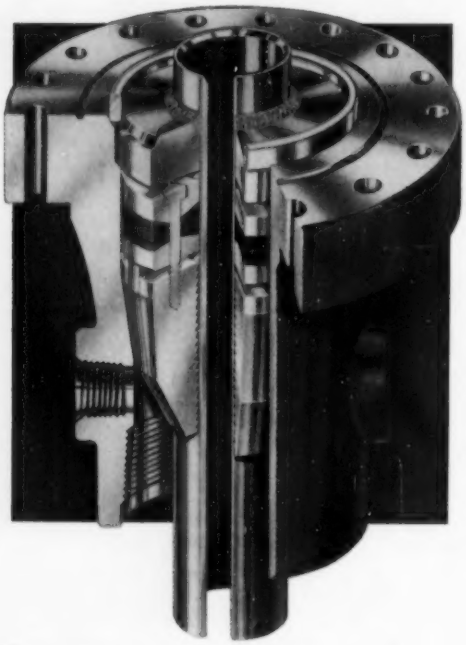
Rector M-4

A low-cost casing head designed for positive trouble-free completions



The Rector Type M-4 casing head is a simple and compact head, designed especially for the safe, economical completion of any medium pressure range well.

The Rector M-4 seals permanently, without the use of resilient packing. It carries a restricted ring groove for final setting which upgrades the working pressure of the flange connection to the next higher rating, permitting connection of the next higher pressure rated tubing head without the use of cross-over flanges.

The Rector M-4 flange has a standard A.P.I. ring groove for attachment of drilling control equipment and is furnished with a removable drilling protector ring.

For economy and dependability choose a RECTOR M-4 casing head for your next completion. Available through your favorite supply store or your RECTOR representative.

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1. *Forward Swept Link Arms* permit easier handling in picking up and laying down pipe.
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Add to these advantages the massive safety latch designed into the body so that the elevator will not be accidentally opened or damaged. Automatic latching results by the simultaneous action of latch and latch lock which close together.

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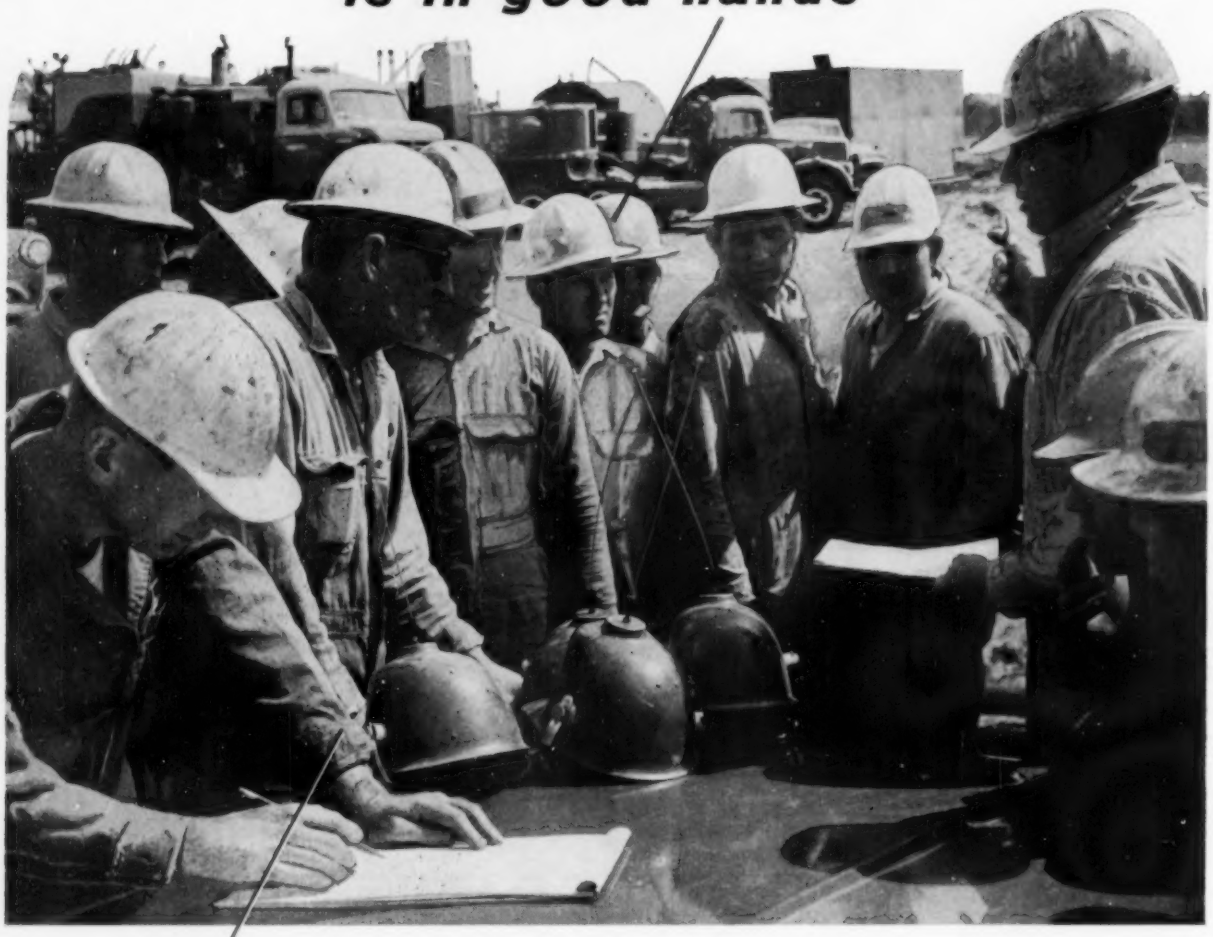

with the HALLIBURTON TEAM

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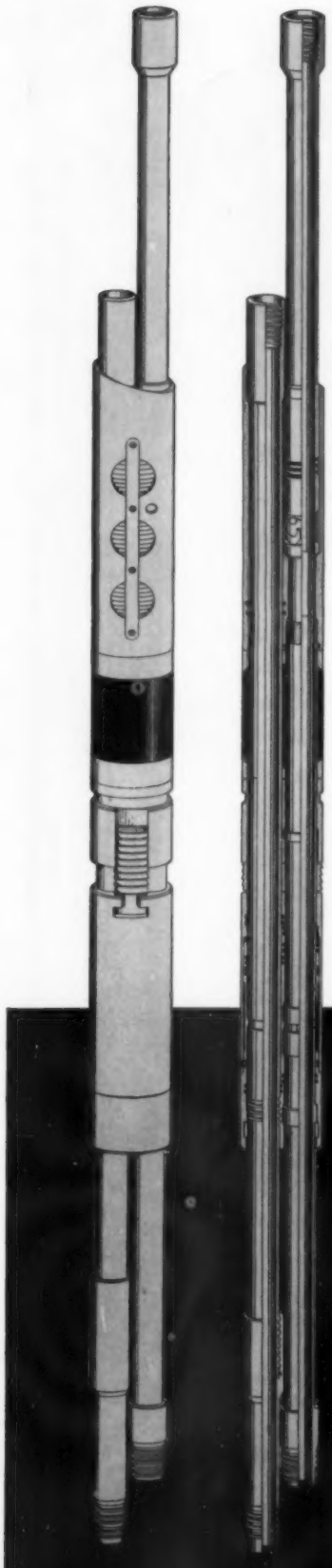

INTRODUCING THE BROWN SERIES HS-17 PACKERS

Although a new series, Brown HS-17 Packers are not a new basic design of Hydraulic Set Multiple String Retrievable Packers — they are an extension of the HS-8 design which has been proven by successful settings in thousands of wells. The only difference between the two designs is the changes that were necessary to meet requirements for larger bores through the mandrels.

Brown Series HS-17 Packers provide the largest bores possible for combinations of tubing strings that can be run in a given casing size. For example, our 7" HS-17-3 (three string) has bores for the first and second strings that will pass a 1⅝" drift. The bore for the third string is the full I.D. of 2-1/16" CS Hydril.

HS-17 Packers are run, set and retrieved in the same general manner as our famous HS-8 Packers.

All of the outstanding features of the HS-8 are retained in the HS-17 series plus the added advantages of larger I.D.'s. These packers are available in sizes 5½" through 7⅝" and for two to five strings.

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RECOVER DRILLABLE PACKERS IN ONE TRIP

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BOWEN PACKER RETRIEVER

Here's the safest, fastest way to recover drillable production packers. The Bowen Packer Retriever will engage, mill-out AND retrieve the production packer—all in a single run.

It's as simple as 1-2-3 — yet you can't lose the packer because the Bowen Retriever is in catching position when it passes through the packer bore. Bridge plugs, cement retainers, and packers can also be milled-out and pushed to the bottom, if retrieving is not required.

In operation, the Retriever (1) Passes through the bore of the packer, in catching position. (2) Mills over the packer. (3) Pulls the the packer.

An added feature: the Retriever is easily disengaged if necessary and re-set again, all without pulling from the hole.

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With BUILT IN POWER SUPPLY

- **Stark simplicity of operation and servicing — you don't need a specialist.**
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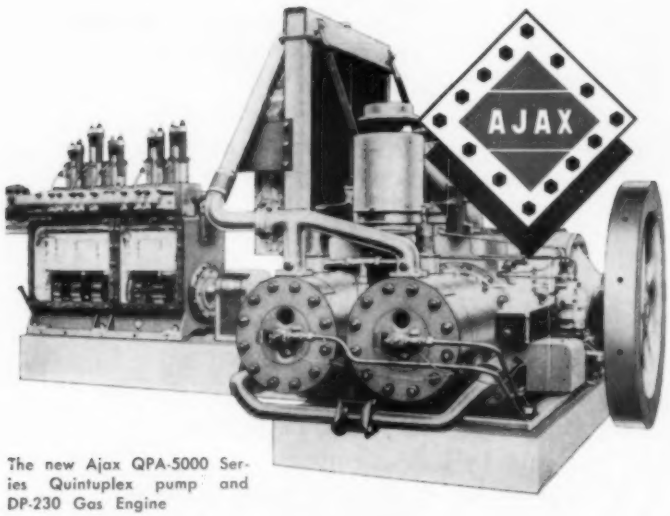

The new Ajax QPA-5000 Series Quintuplex pump and DP-230 Gas Engine

The need for dependable electrical power still remains one of the weak links in the usual automation installation — especially in remote locations and under certain climate conditions.

Ajax time proved engineering has now solved many of the automation-electrification problems. Automation today is economically sound if the equipment and the installation are designed to meet your particular problems. Contact your Ajax distributor today for the full story on automation without external electrification.

Ajax gives you true economy because of simplicity of design, ease of maintenance, extra long life, and 83 years of quality craftsmanship experience.

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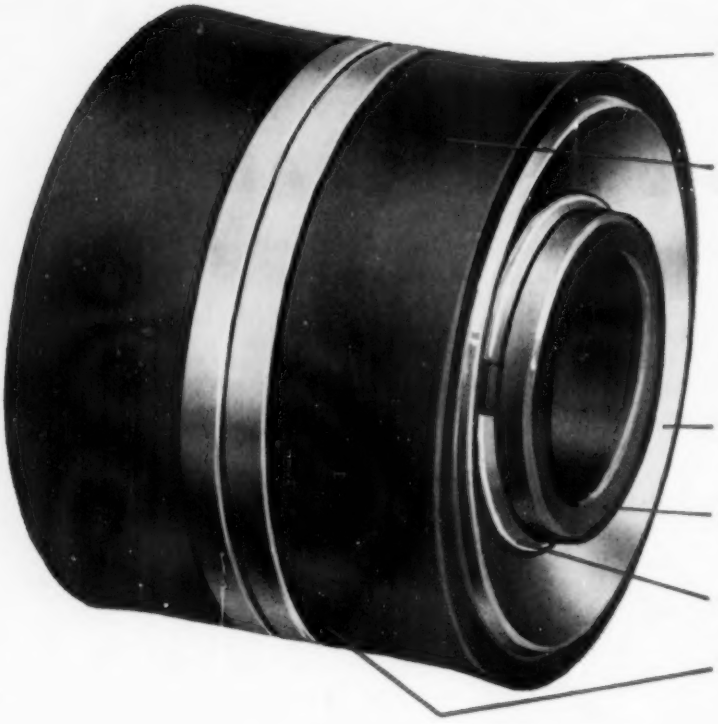
GUIBERSON'S

OIL FIELD TOUGH PUMP PISTON



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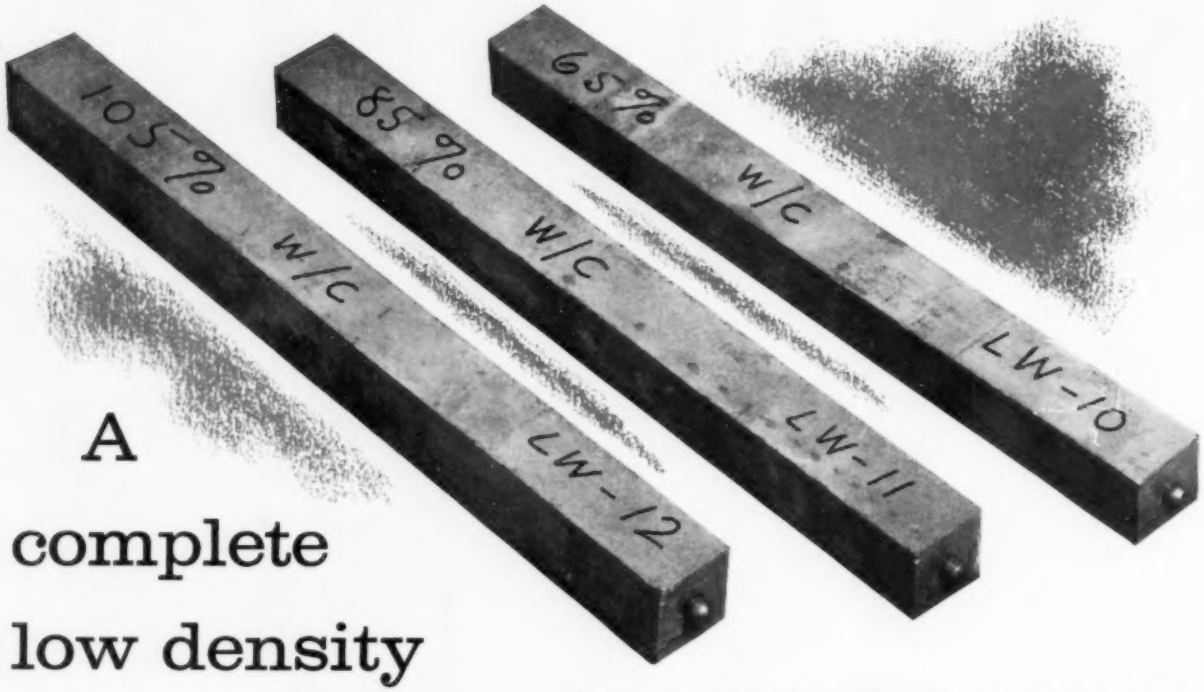

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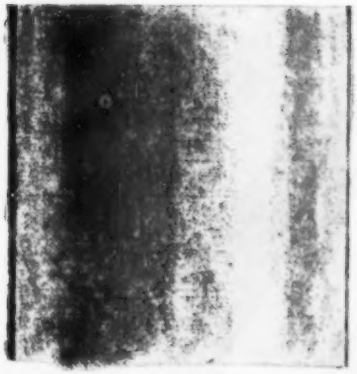

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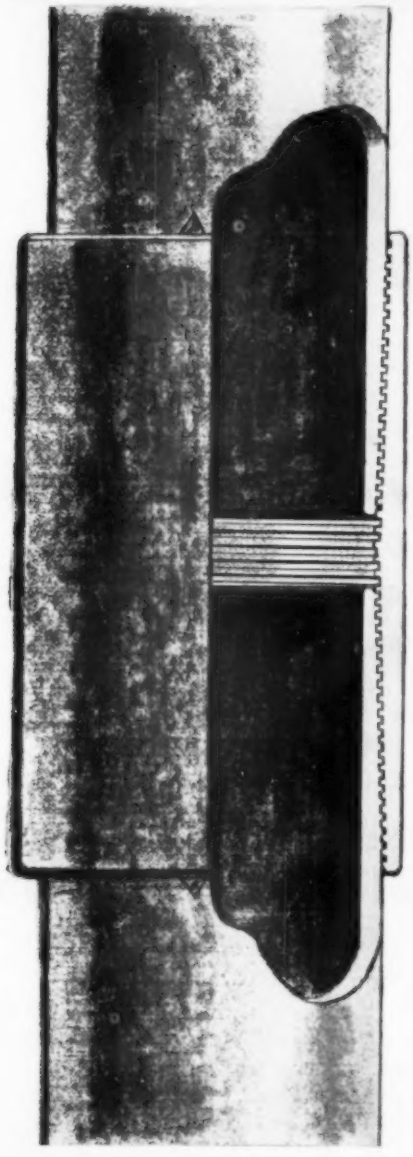

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- Inside clearance is the same throughout the string. There is no internal upset to reduce inside clearance.

For these reasons, Pittsburgh Steel Buttress Thread Casing is the best bet for your next deep well. For descriptive literature and more information, write:

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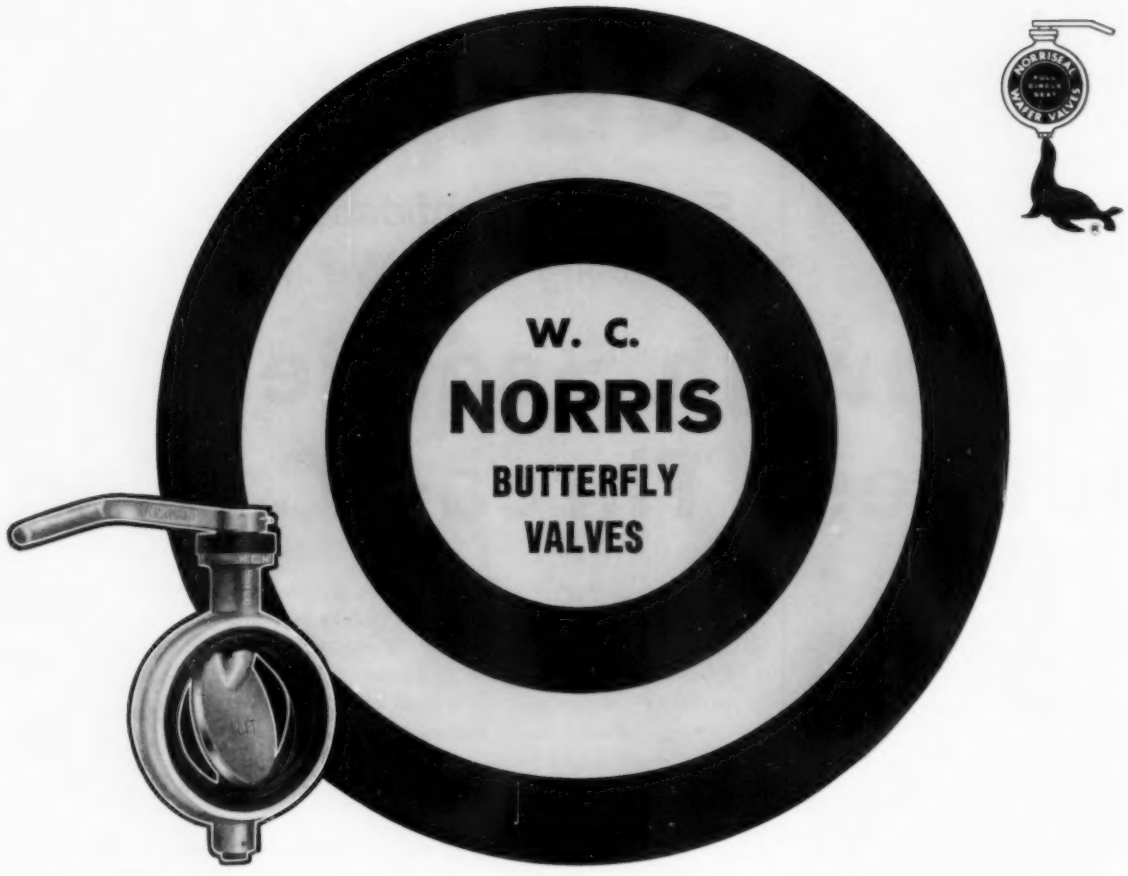

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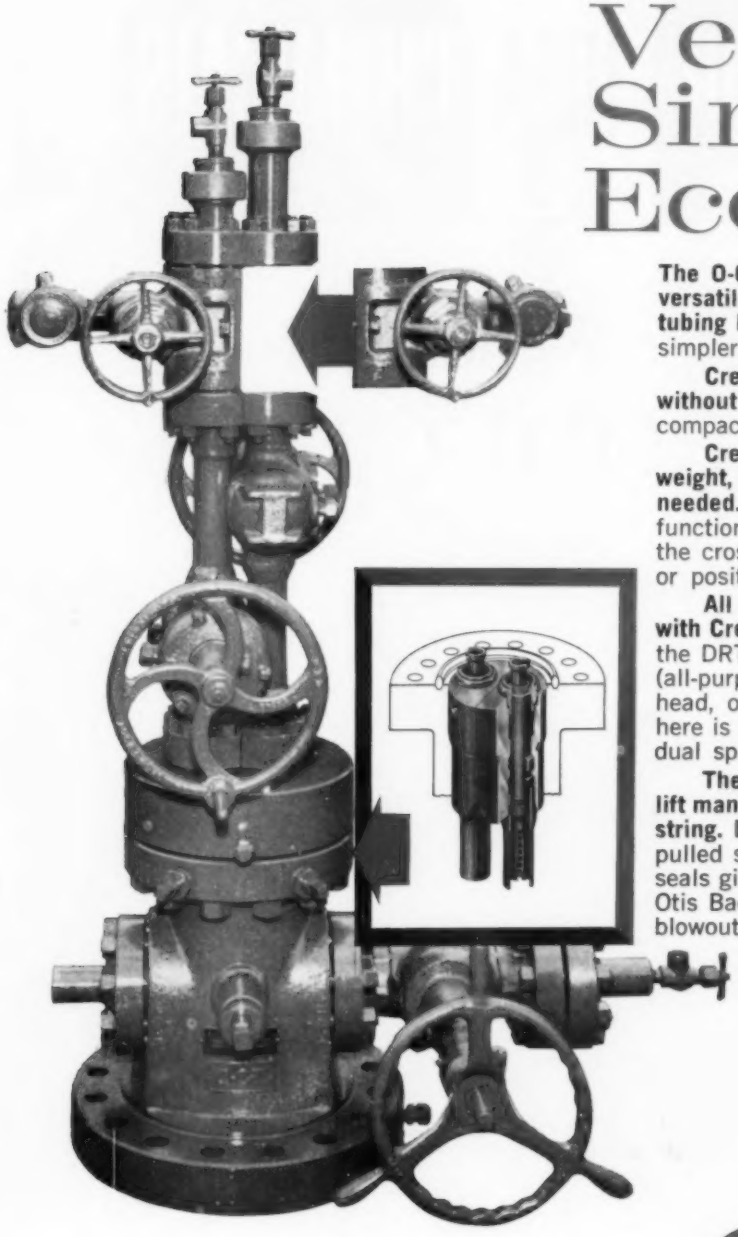

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The dual split hanger permits running gas lift mandrels or packer receptacles on either string. Each semicircular hanger can be run or pulled separately. Compression-type hanger seals give automatic annulus packoff, and O-C-T Otis Back Pressure Valves give complete blowout control after tubing has been landed.

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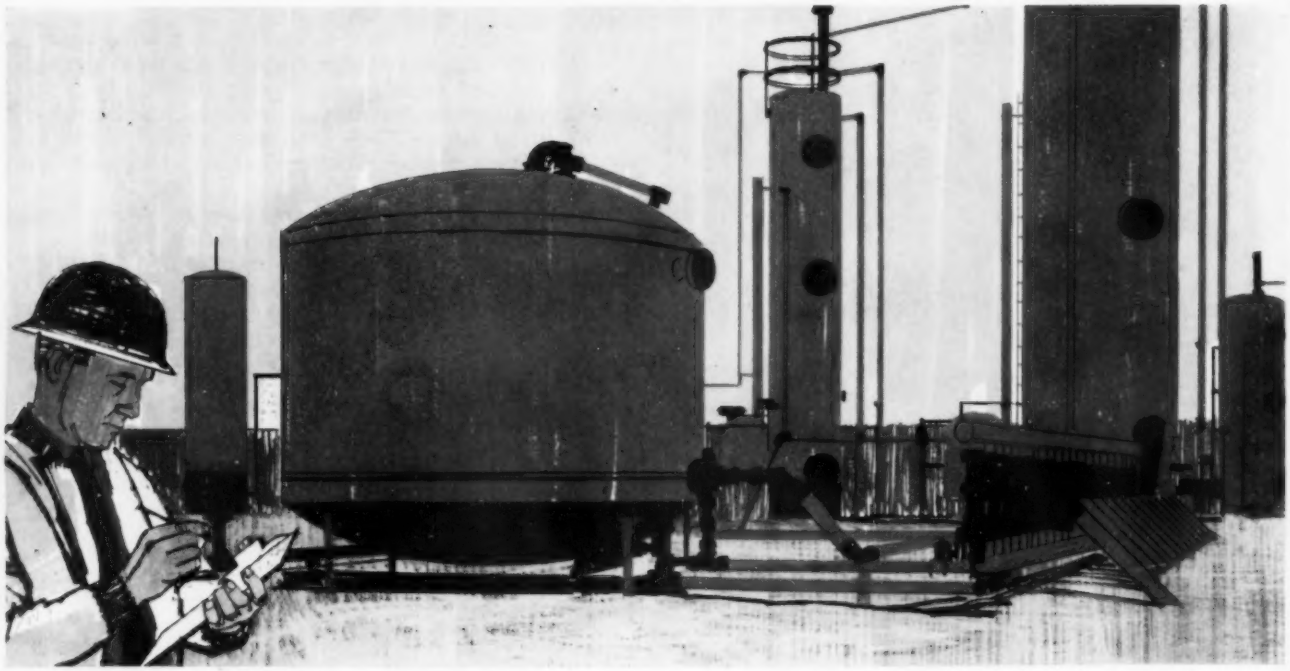

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Several thousand success stories speak for Baker Retrievable Bridge Plugs and the men who run them...

PRODUCT NO. 677-C

Why a retrievable bridge plug in the first place? The reason was a compelling one – there was a need to save time and money on certain important operations *(see right)*.

So a few years ago, Baker developed a new kind of bridge plug. Today, several thousand successful jobs later, Baker Retrievable Bridge Plugs have proved themselves to the satisfaction of operators the world over.

There's a reason for this success. Baker engineers have just one business – and that is designing oilwell tools. Likewise, Baker Servicemen have but one business – and that is running Baker tools. These are the things Baker concentrates on.

Superior tools and professional tool specialists to run them – it's a hard combination to beat. That is why so many operators look to Baker for tools and service.

The Facts About Baker Retrievable Bridge Plugs

WHY RETRIEVABLE BRIDGE PLUGS?

Baker designed them to fill a need for bridge plugs that could be set or reset any number of times without coming out of the hole. Without retrievable plugs, drill-up time alone would be a formidable cost factor in certain operations *(see below)*.

HOW THEY WORK

1 A Baker Retrievable Bridge Plug is run in on the Baker Full Bore Cementer – or by itself on wire line or tubing. Large bypass valves let it run freely.

2 Operation is simple and positive. Once in the hole and released, it sets and packs off automatically – no rotation is required.

3 Packoff is dependable. Two packing cups and two opposed sets of rocker slips hold pressure from either direction. When pressure differential reverses, the packoff reverses automatically.

WHERE AND HOW THEY ARE USED

1 They do many jobs. They see the most action in fracturing, acidizing, and squeeze cementing operations where they are teamed with the Baker Full Bore Cementer.

2 These are the bridge plugs that made conventional straddle tools obsolete. A Baker Retrievable Bridge Plug and a Full Bore Cementer can straddle virtually unlimited distance.

3 Because these plugs are so easy to pick up and relocate, any number of zones can be tested and treated in one round trip.

4 They are also used alone wherever a temporary plug is required down-hole.

5 They are used to plug off just below surface to keep the well under control when working over or testing well head equipment.

6 They are kept available as emergency equipment for offshore wells.

ARE BAKER PLUGS SUPERIOR?

For one thing, Baker Retrievable Bridge Plugs have two sets of opposed rocker type slips. In Baker's opinion, a retrievable bridge plug needs this extra holding power. Moreover, the plug is self-setting. Setting requires neither rotation nor pulling. Note this, too: the bypass valves have no ports or slots to plug up with mud, sand, or junk. They are full-opening 360° valves. These bridge plugs are simple in design, and are simple to operate. That is why they adapt with easy flexibility to the performance of many important operations.

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RETRIEVABLE BRIDGE PLUGS

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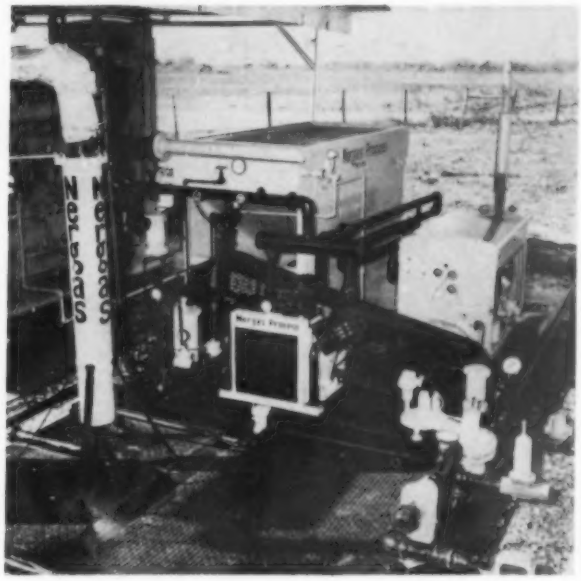
Skid-mounted inert gas generator sits adjacent to large engine driving first-stage compressor (background) at Anse La Butte. Note insulated exhaust line to catalytic reactor chamber (labelled "Nergas") to maintain maximum exhaust temperature.



Catalytic reactor chamber at left (vertical pipe about 40-in. long) is heart of inert gas generator. Fin tube atmospheric cooler is in background, while small two-stage compressor is near center.

In a gas lift operation . . .

CONVERTED ENGINE EXHAUST SUPPLIES MAKE-UP GAS

J. E. KASTROP, *The Petroleum Engineer, Dallas, Texas*

CORROSIVE AND TOXIC ENGINE EXHAUST GASES are converted into an inert gas by a new and novel skid-mounted inert gas generator. Austral Oil Company, Inc., Houston, Texas, has the first commercial unit on field test in its gas lift system at Anse La Butte field in St. Martin Parish, South Louisiana.

Exhaust gases come from a four-cycle, natural gas fueled, conventionally-aspirated engine driving one of two compressors in a closed rotative gas lift system. These exhaust gases are converted by catalytic reaction into a relatively inert product, principally nitrogen, then commingled with natural gas in the system ahead of the compressor suction. This method is different from previous attempts to convert engine exhaust by neutralizing corrosive components, heating and treating, minimizing corrosive constituents by controlling combustion, etc.

In this particular installation, the unit produces about 120,000 cu ft per day of inert product which will provide make-up volume for the system currently handling from 1.2 to 1.6 MMcf per day for rotative gas lifting six producing wells.

The inert gas generator utilizes a process invented by Werner Henke, president of American Machinery, Inc., of Lafayette, Louisiana, who has patents pending on what is called the Nergas Process. Patent and licensing rights have been assigned to the Nergas Corporation which will handle further developments and applications of the process.

Need for Make-Up Gas

Anse La Butte is one of the older oil fields in South Louisiana and has seen many years of prolific production. In the last 4½ years, productivity has declined, and many wells are on some form of artificial lift. Production comes principally from three horizons of Miocene age. The lower reservoir is a "MargTex" sand that produces from perforations ranging in depth from 10,000 to 11,000 ft. The upper formation is the "Het" limestone where producing depths range from 7600 to 7800 ft. The middle reservoir is a prolific discorbis sand found from 8200 to 8400 ft. The lower zone is characterized by gas-oil ratios between 2000 and 3400. Gas-oil ratios in upper zones are generally below 500. Fluid levels remain fairly high at about 2500 ft.

Austral's first gas lift installation at Anse La Butte was made in December 1956. At that time the company operated 11 wells: Eight flowed; one was on gas lift; and two were temporarily shut-in. The number of wells placed on gas lift increased and during most of 1958 and the early part of 1959, as many as seven wells were produced by gas lift. At this writing, Austral has four flowing wells, two wells are shut-in and six are gas lifted.

Formation gas production decline. Until the fall of 1960, formation gas production from all of Austral's wells at Anse La Butte averaged about 768,000 cu ft per day. In recog-

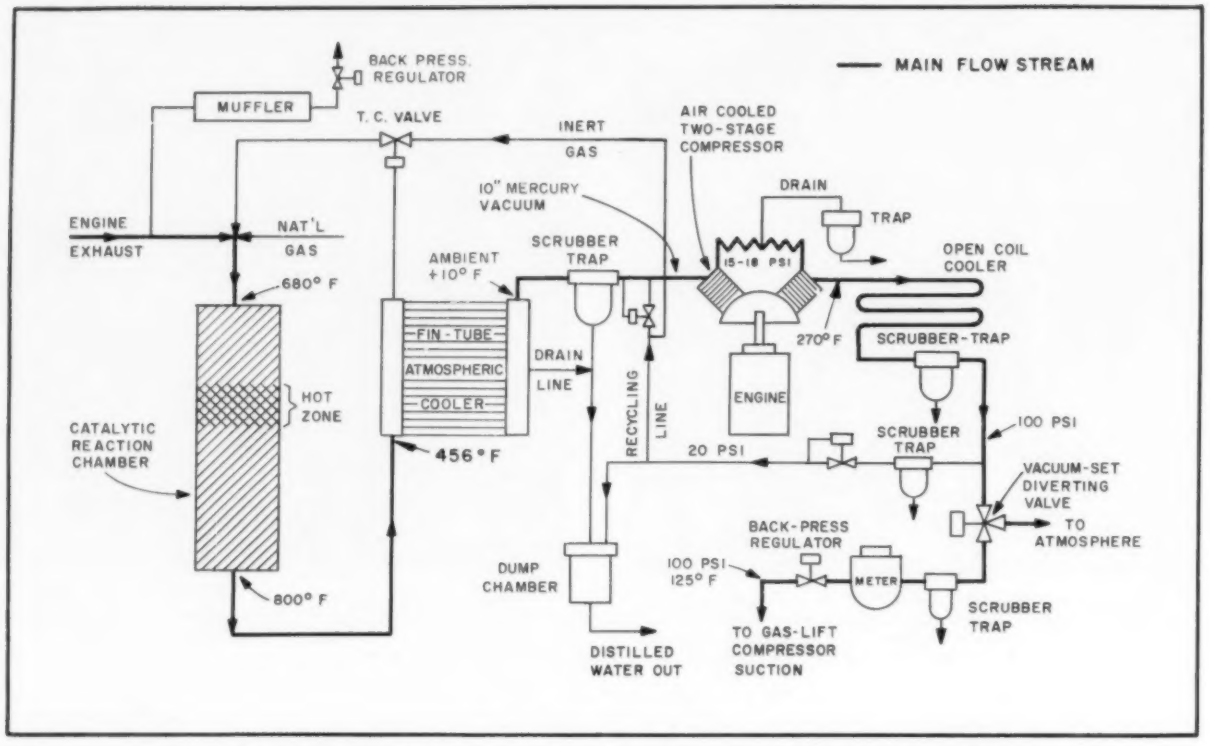


FIG. 1. **Inert gas generator** is not a complicated process unit. The dark line traces the main flow through this schematic diagram which relates the principal components and primary control systems.

nizing the declining characteristic of the wells, Irwin R. "Bud" Chalmers, Austral's district production superintendent at Lafayette, became concerned over the prospect that at some future date it may be necessary to buy gas lift make-up gas for the system. Nearest source of gas supply at the relatively small quantities that would be needed was from a transmission line via a local town's utility system at 30 cents per Mcf and a guaranteed "minimum take." Austral's gas lift system handled from 1.2 to 1.6 MMcf per day, and make-up requirements were roughly estimated to be about 10% of this daily volume.

By fall of 1960, formation gas production averaged about 650,000 cu ft per day, and by January 1961 this volume had dropped further to 550,000 cu ft daily. Also of concern to superintendent Chalmers was the fact that the water cut on some producing oil wells was increasing, and it would be only a matter of time when some of the flowing wells would require gas lift.

Although Austral's Anse La Butte gas lift system does not now require outside make-up gas for its gas lift operations, at the present rate of decline in formation gas production, it is only a matter of time. In looking for a possible outside source of make-up gas when that time does arrive, it was fortunate that Henke's Nergas Process was beyond the development stage and ready for a field test. The first Nergas Generator was installed in Austral's gas lift system in February and is now supplying about 120,000 cu ft per day.

PROBLEM OF EXHAUST GAS CONVERSION

Exhaust gases have long been recognized as a potential source of gas. There are billions of cu ft of these exhaust gases blown into the atmosphere every day. Volumes available from small engines are quite high. For example, a natural aspirated gas fueled engine will normally consume about 10 to 14 cu ft of natural gas per delivered horsepower hour. This is a rule-of-thumb and depends on a number of varying factors such as condition of engine, loading, etc. And to burn this natural gas, oxygen is required. If perfect combustion is achieved, it requires about 10 cu ft of air (which contains about 21% oxygen) for every cu ft of natural gas. This is the air-to-fuel ratio. Rarely is perfect combustion achieved, and in most gas engines in fairly good condition, the air-to-fuel ratio is about 12 to 1.

On this basis, let's calculate the volume of engine exhaust available per day from a four-cycle, conventionally aspirated (not supercharged), natural gas engine.

$$V_x = 100 \text{ hp} \times 12 \text{ cu ft gas} \times 12 \text{ cu ft air} \times 24 \text{ hours}$$
$$= 345{,}600 \text{ cu ft per day}$$

where

V_x = engine exhaust volume at atmospheric conditions.

While a 100-hp gas engine will discharge theoretically about 345,600 cu ft of exhaust, there is a contraction of volume since water is produced from the combustion reaction. The degree of this volume shrinkage due to water vapor depends upon the number of hydrogen atoms in the gas (CH_4, C_2H_4, etc.) to react with oxygen in the air to form H_2O, or water. For approximate calculations, this shrinkage in volume from the calculated value of V_x above, is conservatively estimated at 10%.

Composition of Exhaust Gases

Analysis of gas engine exhaust show that it contains 89% nitrogen. Remaining components are: water vapor (H_2O); carbon dioxide (CO_2); oxygen (O_2); carbon monoxide (CO); hydrogen (H_2); oxides of nitrogen (NO, NO_2, etc); aldehydes (HCHO, etc.); organic acids (HCOOH, etc.); alcohols (CH_3OH, etc.); hydrocarbons (C_nH_m); and smoke. These components will vary somewhat depending upon the Btu content of the fuel, the characteristics and composition of the fuel, the water content of the air, combustion efficiency, etc.

It is well known that some of these components are corrosive. Oxides of nitrogen formed in the combustion process are odorless and only slightly corrosive in the presence of water. But when nitric oxide is oxidized by oxygen in the presence of water, nitric acid (HNO_3) is formed. It is extremely corrosive. Unburned oxygen in engine exhaust (due to incomplete combustion) is undesirable because of its corrosive and explosive nature.

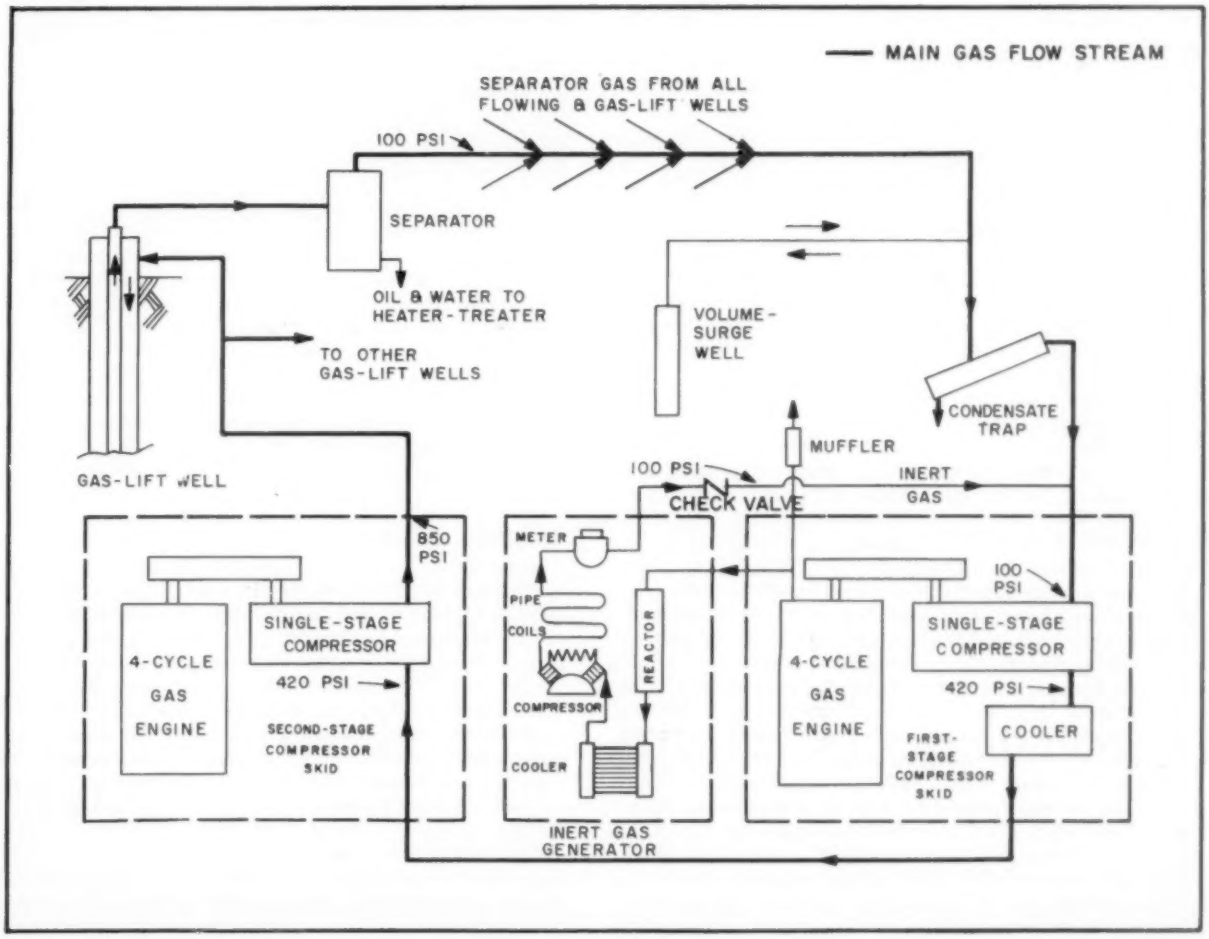
Conversion by Catalytic Reaction

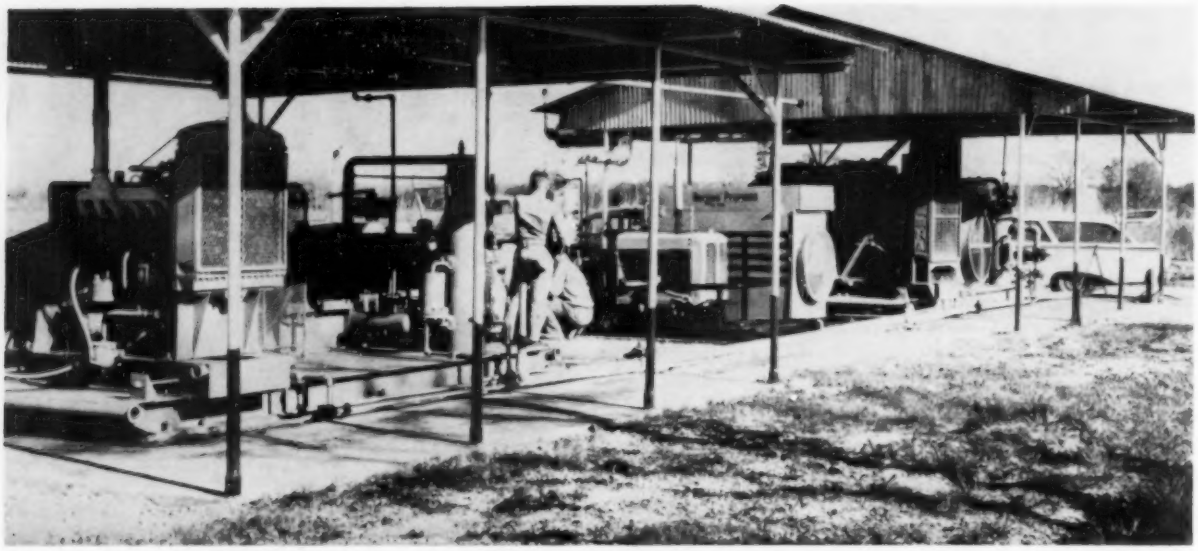
Since the combustion in most gas engines in field operation is not perfect, the exhaust gases will contain from 2 to 6% oxygen. This is just enough oxygen to accomplish further combustion, and in the presence of a catalyst, alter the composition of the exhaust gases to use up all the oxygen and convert the oxides of nitrogen into nitrogen gas and water vapor. The remaining product is principally nitrogen . . . about 89% and 11% carbon dioxide.

What causes this secondary combustion? In the presence of a catalytic material . . . such as one of the precious metals . . . at reactive temperatures . . . unburned oxygen reacts with some of the most reactive components in the exhaust gases. In this case . . . as well as in all catalytic reactions employed in petroleum processing for many years . . . the catalyst merely stimulates the reaction between two compounds, but does not enter into the reaction itself. Therefore, the catalytic material does not alter its composition. Heat required for the catalyst to become reactive is supplied by the heat in the exhaust gases, the temperature of which may easily exceed 1000 F at the engine exhaust manifold.

Fin-tube cooler with forced air circulation is shown at right in relation to the gas engine which drives the small two-stage compressor of the inert gas generator.

FIG. 2. **Closed rotative gas lift system** at Austral Oil Company's Anse La Butte lease shows how the inert gas generator fits into the system to supply 120,000 cu ft daily for make-up gas. Dark line shows main gas flow stream through the gas lift system.





Austral Oil Company's Anse La Butte compressor station includes two separate single-stage packaged compressors. The inert gas generator is located between the two compressor units.

A catalytic reaction chamber packed with a catalyst which has a relatively low reactive temperature is the heart of the inert gas generator.

How the Inert Gas Generator Works

Fig. 1 shows the principal components of the generator and a simplified flow diagram of the main flow stream and auxiliary control systems. Since engine exhaust is diverted directly from the exhaust manifold into the catalytic reaction chamber, it was essential that no back-pressure be imposed on the engine itself. Design and fabrication of the inert gas generator had to consider this important operating requirement. Also, an excessive vacuum could not be tolerated since this would tend to "suck" into the system an excess of unburned air. A special back-pressure valve on the engine exhaust restricts this pressure from 8 oz per sq in. to a maximum of 10 oz per sq in.

Major components of the generator include the catalytic reaction chamber, an atmospheric fin-tube gas cooler, adequate scrubbers and traps to remove water vapors, a small compressor, an after cooler (open pipe coils), back-pressure valves and gas meter. All components up to the small compressor suction must function under a vacuum and must not allow the entry of any air.

Exhaust gases enter the top of the catalytic reaction chamber, a section of 5½-in. pipe about 40 in. long, and discharge out the bottom through a 2-in. pipe. Temperature of the exhaust entering the reaction chamber is approximately 680 F; discharge temperature is around 800 F (depends on amount of oxidant present). Composition of the hot gases coming out of the reaction chamber is essentially water vapor, nitrogen and carbon dioxide. These products flow directly into a four-pass fin-tube, forced circulated, atmospheric cooler. Gases are cooled to within 10 F of ambient temperature. Water vapors condensed by cooling are collected from the cooler itself and in a scrubber-trap that discharges collected water by gravity into a vacuum type lift trap, then forced into a collecting vessel. This water is relatively pure in nature and has a pH of 8.3.

At this point, the system is still under a vacuum of less than 10-in. of mercury. The inert gas enters the suction of a small (20-hp) two-stage, air-cooled compressor. Interstage pressure is about 15-18 psi and discharge pressure in this particular gas lift application is about 100 psi. Temperature at compressor discharge is near 270 F, but rapidly cools through an open 2-in. pipe coil. Main flow is through a positive-displacement type gas meter, a back-pressure regulator to maintain a 100 psi line pressure on the generator and into the gas lift gathering system.

All equipment of the inert gas generator has been mounted on a skid 8 ft wide by 14 ft long. Ample space was provided for all components on this first commercial model, and its developers anticipate future models will be considerably smaller for the same capacity. The unit must discharge the inert gas into a gas lift gas gathering system which operates at 100 psi, which is somewhat higher than comparable gas gathering systems in most closed rotative gas lift installations.

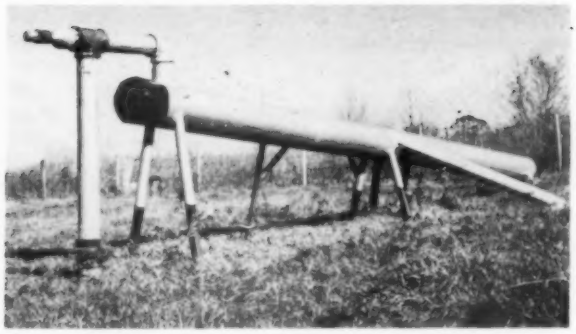
At present, the unit produces about 120,000 cu ft of inert product containing about 89% nitrogen and 11% carbon dioxide at 100 psi back pressure held on the small two-stage compressor. The capacity of this unit can be increased considerably by reducing this back pressure, to say around 50 psi, for feeding into a 40-psi line. And the capacity of the unit also can be increased by using a larger size compressor.

Gas cooling more rapid than expected. Although gas comes out of the reactor chamber at 800 F, heat is rapidly dissipated in the exposed piping. For example, this temperature drops to 456 F in the short pipe run to the cooler. And, at the end of the first pass in the 4-pass atmospheric fin-tube cooler, the temperature drops to almost atmospheric temperature.

Auxiliary Controls

Once the unit starts operating, it is automatic. And start up procedure is relatively simple. Exhaust gas is "sucked" through the unit by the compressor and vented through the "source-engine vacuum-set diverting valve" on the discharge side of the small compressor unit until the reactor attains its proper reactive temperature. At this temperature, the catalyst becomes reactive to cause the secondary combustion necessary for the chemical conversion of the undersirable components of the exhaust gases. Once this temperature has been reached, the diverting valve is closed, and the products are fed through the meter and into the gas lift gathering system.

Should the suction vacuum of this system exceed operating values, a vacuum-sensing pilot and motor valve will route a portion of the discharge product back into the suction of the small compressor until the vacuum of the suction



Condensate drip collects all liquids from separator gas before discharging into first-stage compressor suction. Vertical 3-in. line at left connects directly to compressor suction. Separator gas lines connect into rear of condensate drip.

Inventor Werner Henke of Lafayette, Louisiana, carefully checks temperature at all critical points in the inert gas generator by means of thermocouples. Chemical content of produced inert gas is also checked and compared with engine exhaust gas to determine efficiency of the process.

line drops to the proper value. A high vacuum cut-off gauge is also provided. Should the large engine driving the main gas lift compressor slow down or die, gas from the 100 psi side of the small compressor is automatically vented to the atmosphere to prevent untreated product from entering the gas lift system.

Pressure in this recycling line is maintained at about 20 psi and is a source of pressure gas for other control valves. When the dump chamber fills with condensed water vapor, which at the time of filling is under a vacuum, the vacuum balance line is closed and the pressure line is opened to blow out collected water into a collecting vessel. This is all automatic.

Should the main compressor engine supplying exhaust gas begin to miss or otherwise malfunction so as to increase the oxygen content (due to unburned fuel) in the exhaust stream entering the unit, the reactor temperature increases. Normal operation of the inert gas generator is usually set for oxygen content of the exhaust gas of from two to four percent oxygen. However, when this oxygen content goes higher, secondary combustion is increased accordingly, and increases the temperature of the gas coming out of the reaction chamber.

To prevent the temperature in the reactive chamber exceeding desirable limits, a temperature-controlled valve was placed in the fin-tubed atmosphere cooler. When the temperature at this point exceeds a pre-set level, converted gases from the re-cycling line are diverted back into the top of the reaction chamber. Purpose here is to dilute the exhaust gases so oxygen content of the incoming stream is cut back to not more than 7 or 8%, and temperature of the secondary combustion in the reaction chamber is reduced to operating conditions.

In case the reactive temperature is not high enough to assure complete oxidation and conversion of the undesirable exhaust gas components, provisions were made to add a small amount of natural gas to the incoming exhaust stream at the top of the reaction chamber, as shown in Fig. 1.

A moisture-free product is assured by installing scrubber-traps at strategic points throughout the flow stream. On the vacuum of the small compressor, drain lines from these critical points connect into a vacuum-type lift trap. Moisture collected in the scrubber traps on the pressure side of the small compressors dumps into an atmospheric drain system.

The amount of water produced from the generator varies with the moisture content in the air, composition of the fuel to the compressor engine, efficiency of combustion, etc. However, at Austral's gas lift installation at Anse La Butte where the inert gas generator is producing about 120,000 cu ft daily, it is estimated from short-run checks that about 60 gal of water are produced per day. Under steady-state operations, the generator produces at the rate of about 83 cu ft per min of inert gases and with it a little over one-third pint of condensed water vapor.

The Carbon Dioxide Question

Inert gas produced by the generator contains about 11% carbon dioxide and 89% nitrogen. Some may question the corrosive factor of CO_2. Does it or doesn't it result in corrosion? The literature indicates a divergence of view point by corrosion engineers based on laboratory work and field studies. Some draw the conclusion that it neither directly nor indirectly results in corrosion in itself. Field men are dubious and concerned. It is not the purpose here to prove or disprove any theory or field results in this case. But we do know that carbon dioxide gases are being used in the so-called "soda-pop" water floods and there are at least two such floods now in operation in the U. S. Also, the use of inert gas for repressuring is not new. These projects utilized treated flue gases which contain up to 12% CO_2. One such project in Wyoming has been in operation for many years.

However, provision has been made on the inert gas generator to inhibit the carbon dioxide if desired. A special type of chemical inhibitor was developed and requires only a half pint per 2 MMcf for complete inhibition. It is injected into the inert gas generator stream at the end of the first pass of the fin-tube atmospheric cooler. At this point, there is an 8 to 10-in. mercury vacuum in the system.

Inventor Henke's patent application does include a method of removing almost completely all carbon dioxide if this is required, or cleaning up compressor engine fuel gas (which may contain H_2S or CO_2). It is another section added to the present inert gas generator described above. Instead of flowing the produced gas into the system at a prescribed pressure, the gas is diverted into a washing or scrubbing vessel. In this vessel, the gas flows from bottom to top, while an alkaline solution (such as sodium carbonate, ammonium hydroxide, etc.) is sprayed downward. This caustic wash absorbs the CO_2 (or H_2S) leaving essentially pure nitrogen (about 99.8% pure). The alkaline solution is recirculated, the spent solution removed and additional treating solution continually added in an automatic system.

Application in Austral's Gas Lift System

Fig. 2 shows how the inert gas generator fits into Austral Oil Company's Anse La Butte gas lift system. At the present time, there are four flowing, six gas-lift and two shut-in wells. Separator back-pressure is set for about 100 psi. All separator gas is collected into one system, flowed through a gravity-type condensate trap before entering the suction of the first-stage compressor. An abandoned well which has 10¾-in. casing cemented to a depth of about 825 ft serves as a volume surge chamber as indicated in Fig. 2.

At Austral's compressor station, gas enters the first stage compressor (a single stage unit) at about 100 psi. The gas is compressed to about 420 psi, cooled and piped to the suction of the second stage compressor. There, a single-stage compressor discharges the gas at about 850 psi for distribution to the casing annulus of all gas-lift wells operated by Austral at Anse La Butte.

The inert gas generator skid is adjacent to the first-stage compressor skid as shown in Fig. 2. It is located as near the driving engine as possible to reduce the length of 3-in. pipe which carries exhaust gases into the inert gas generator. By shortening the length of this line, temperature of the exhaust gas is retained to provide the necessary temperature in the catalytic reactor chamber.

Inert gases from the generator are piped by a two-in. line connecting back into the separator gas collecting system as shown. About 120,000 cu ft daily of this inert gas product is added to the 1.2 to 1.6 MMcf per day stream for gas lifting producing wells. Fuel for both engines driving the compressors and for the engine driving the 20-hp compressor of the inert gas generator is taken off the discharge side of the second-stage compressor. What effect this 10% dilution of natural gas with inert gas will have on operating characteristics of the engines is yet to be seen. Undoubtedly, there will be a time several years hence perhaps, when it will be necessary to purchase outside gas for engine fuel. Or, engine fuel can be taken directly off the field separators. Even at 30 cents per thousand cu ft, the cost of fuel at some future date would be less than $10 per day. But, if it were necessary to purchase all make-up gas at this rate, 120,000 cu ft per day would amount to $1080, per month, exclusive of the engine fuel costs.

Other Potential Field Uses

Success of this first commercial model of an inert gas generator to supply gas lift make-up gas should be a most welcomed development to other producers facing similar problems. It is anticipated that various sized models will be available to cover a wide range of capacities. Other potential oil field uses include: (1) air/gas drilling; (2) diluting high Btu content field gas to contracted Btu levels; (3) repressuring; (4) attic oil recovery; (5) recycling; and (6) testing of piping system and purging.

Acknowledgment

For supplying data and for permission to prepare and publish this report, the author is grateful to Werner Henke, inventor of the Nergas Process, and to Irwin R. "Bud" Chalmers, District Production Superintendent for Austral Oil Company, Lafayette, La. ★ ★ ★

DIFFERENTIAL LIBERATION INCREASES LIQUID RECOVERY

J. A. PERKINS, JR., *Perkins & Quinn, Houston, Texas*

New idea in separators uses laboratory procedure to increase liquid hydrocarbon recovery 10 - 15% while stabilizing oil and condensate at the same time

A PHENOMENON well-known in laboratory analysis of hydrocarbons has been incorporated into the design and operation of a new-type oil and gas separator. Logically called the differential liberation separator . . . DLS for short . . . this new idea not only increases liquid recovery, but stabilizes both the condensates and oil as well. It is best employed in conjunction with existing oil and gas separation equipment. Experience so far has indicated in general that hydrocarbons of high gravity show the greatest stock tank gain when differential liberation separation is employed. It is especially suited for use on gas condensate producing wells during the interim period from the time the well is brought in until the total well stream is connected to a plant.

The commercial unit is skid-mounted, highly compact and portable, requires no heat or special facilities and is completely automatic.

To determine specific application of the DLS unit, a first stage separator liquid discharge sample is analyzed in the laboratory by both the flash and differential process to determine the approximate stabilized liquid gain to be anticipated by differential liberation. Tests indicate that from 10 to 15% more liquid can be recovered and saved by the use of differential liberation separation over conventional flash-type separation, especially low-temperature and dry-desiccant methods.

Difference in Flash and Differential Separation

The flash process is the evolution of vaporization of dissolved gas from a hydrocarbon liquid under constant total composition conditions, terminating in thermodynamic equilibrium at the final conditions of temperature and pressure. The occurrence of a flash process in a crude oil-gas system is characterized first by the constancy of total composition during vaporization, and secondly by thermodynamic equilibrium at the terminal point of the process. For example, in a closed variable volume vessel the overall composition of any system would be unaltered by changes in temperature and pressure; only the distribution of the components between the gas and liquid phases would be affected. In a flash process the pressure decline may be more or less instantaneous, such as that caused by a throttling valve or choke in

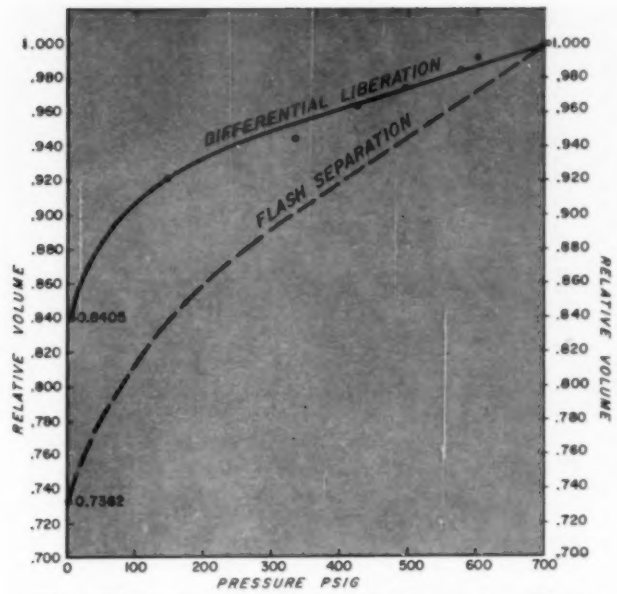


FIG. 1. **Relative volume increase** of liquid recovery from Alligator Bayou field of Chambers County, Texas, with flash and differential liberation separation. Increase was 10.43% over flash separation as compared to differential liberation.

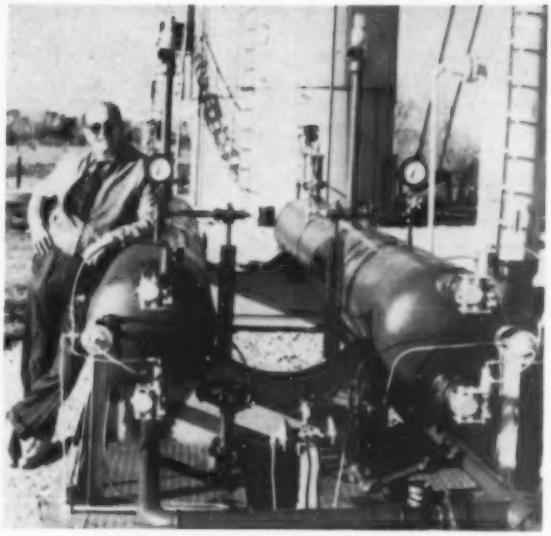


FIG. 2. **Differential liberation separator** on field location in Gulf Coast. Standing beside unit is Hienz K. Rohde, chief design engineer for Parks Equipment Company of Houston, Texas, holder of patents on the unit.

a flow line, or it may be gradual and continuous. The manner in which a flash process proceeds from inception to completion is immaterial; the initial composition and final conditions of temperature and pressure alone govern the end result.

Conventional oil field separation practice conforms to the flash process in that it follows the principle of vaporization under "constant composition" conditions, i.e., the complete vaporization to equilibrium of oil and gas occurs in the separator before either oil or gas is withdrawn from the system.

The differential process is the vaporization and subsequent separation of dissolved gas from a hydrocarbon liquid in such a manner as to maintain throughout the pressure decline both a continuous change in the compositions of the gas and liquid phases and, to the extent possible, a state of disequilibrium between phases.

The differential process is characterized by an overall change in composition resulting from separation and removal of evolved gas, as well as by continuous variation in the composition of gas and liquid phases during the separation process. Separation of the segregated phases, which results in the overall composition change, is effected concurrently with gas evolution or immediately upon termination of the gas evolution. Terminal separation, i.e., removal of the gas phase at the conclusion of the pressure decline, cannot be used if the pressure decline induces retrograde condensation in the gas phase. When such is the case, concurrent separation must be employed. If retrograde condensation does not occur, either concurrent or terminal separation would satisfy the requirements of the exact differential process.

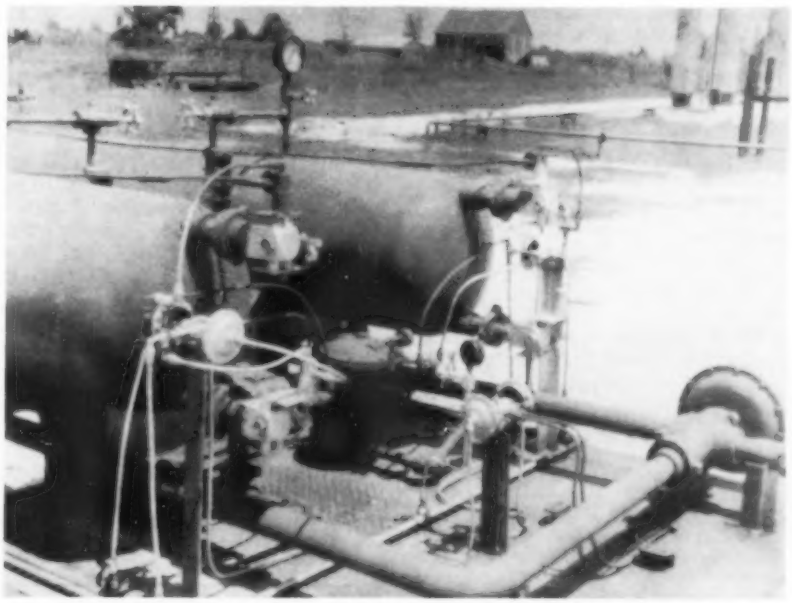


FIG. 3. **Pressure and flow controls** on differential liberation separator are automatic. In lower right hand corner is the three-way flow control valve for alternating fillup of the two chambers.

Application of Process

In conventional flash separators utilized in general oil field operations a continuous feed of well fluid enters the separator while separation occurs. This is accomplished under a more or less constant pressure and temperature. Under the condition of new material being added while gas is taken off simultaneously with the liquid, a very turbulent condition exists within the separator as far as the different hydrocarbon components are concerned. Light ends along with some heavier components go to the gas line and some

of the light ends join with the heavy ends going to the tanks in the form of liquid. Heavy ends going off with the gas are lost to the producer. The light ends going into the tank along with the liquid will, upon entering the lease tanks under normal conditions, revert to a gas and take some of the heavier ends with them resulting in an evaporation loss. This phenomenon is one of "association" and grossly affects the intermediate group of hydrocarbons which are in the critical range and can become either liquid or gas depending upon whether they are associated with the heavier or light ends.

How the Two Processes Differ

The differential process is basically different from the flash process inasmuch as new material from the well is not permitted to enter the separation chamber during separation. This permits a grouping of the various components into their relative weight positions as separation occurs. As the light ends begin to evolve due to continuous pressure reduction, they are vented so as to prevent mixing with the heaviers and causing trouble in the tanks later. This assures a better stabilized and higher gravity liquid in the stock tank.

Table 1. Podbielniak Analysis of Separator Liquid at 585 Psig and 84 F from Alligator Bayou Field of Chambers County, Texas.

Component	MOL%	Liquid Volume %
Methane	17.03	7.42
Ethane	5.15	3.37
Propane	6.89	4.87
Iso-Butane	3.41	2.86
N-Butane	4.77	3.86
Iso-Pentane	4.77	4.48
N-Pentane	3.48	3.24
Hexanes	9.54	10.08
Heptanes (Part.)	3.94	4.67
Heptanes +	41.02	55.15
	100.00	100.00

C_7 Residue: API Gravity at 60 F = 49.8
Specific Gravity at 60 F/60 F = .7806
Molecular Weight = 129

Table 2. Podbielniak Analysis of Separator Gas at 585 Psig and 84 F from Alligator Bayou Field of Chambers County, Texas.

Component	MOL%	Gpm @ 14.65 psia
Carbon Dioxide	0.53	
Methane	89.12	
Ethane	5.49	
Propane	2.79	.765
Iso-Butane	0.65	.212
N-Butane	0.69	.217
Iso-Pentane	0.24	.087
N-Pentane	0.18	.065
Hexanes	0.20	.082
Heptanes +	0.11	.050
	100.00	1.478

Computed Specific Gravity (Air = 1.0) = .652
Determined Specific Gravity = .644
Computed 26-lb Gasoline Content = .406 gpm

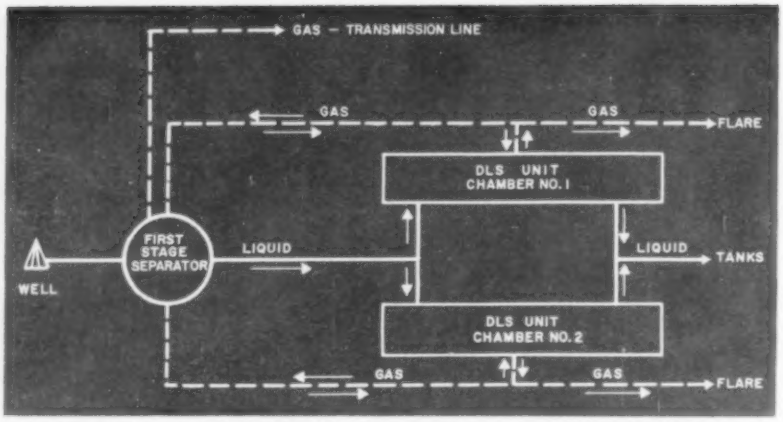


FIG. 4. **Flow of gas and liquid** through unit is from first-stage separator then into either of the two chambers. Gas goes back to first-stage separator, or to flare line when pressure exceeds a set value.

Field Application

The unit is so arranged that it can be used as the only separation mechanism needed from the well to the tanks. From a practical standpoint, this type of hook up has certain disadvantages in that a compressor would have to be used to pick up the gas in the low pressure range of discharge from the DLS unit to meet the existing transmission line pressure. A better arrangement would be to use existing high pressure flash separating equipment and install the differential unit as a second stage. This would not materially reduce efficiency, as the differential liberation separator accomplishes its greatest benefit below 125 psi. In this hook up, the unit would process only the liquid leaving the first stage separator.

How the Separator Works

As shown on Fig. 4, the unit consists basically of two chambers. Fluid from the well enters a conventional flash separator, low-temperature or dry desiccant unit and the first-stage separation occurs. The gas goes to the transmission line and the liquid is gravity fed to chamber No. 1 of the unit.

When liquid fills the chamber, flow is automatically switched to chamber No. 2. Simultaneously, a pressure equalizing line from the first stage separator to the top of chamber No. 1 closes and a flare line opens. This slowly reduces the pressure to a predetermined point in the chamber, usually one to two psi.

When this pressure reaches a set minimum, the flare line closes and the pressure equalizing line opens. A liquid line to the stock tanks also opens. This purges the stabilized liquid out of chamber No. 1 to the stock tank.

When liquid reaches the lower level limit in the chamber, the tank line closes and chamber No. 1 stands ready to receive liquid again. As soon as chamber No. 2 fills and starts a similar cycle, the flow of liquid is switched from the first stage separator back to chamber No. 1 again. There is no interruption in the well's production or the operation of the first stage separator. The entire operation is fully automatic. ★ ★ ★

ABOUT THE AUTHOR

James A. Perkins, Jr., is a partner in the petroleum engineering consulting firm of Perkins & Quinn with headquarters in the Bank of the Southwest Building, Houston, Texas. After graduating from Louisiana State University with a BS degree in petroleum engineering, he joined Gulf Oil Corporation's exploration department. After transfer to the production department, he worked in the field as roustabout, clerk, roughneck, field engineer and later advanced to chief engineer of Gulf's Houston district. He then was made division reservoir engineer, and in 1957 left Gulf to form the consulting firm of Perkins & Quinn specializing in all phases of drilling and production including property management, reservoir analysis and secondary recovery.

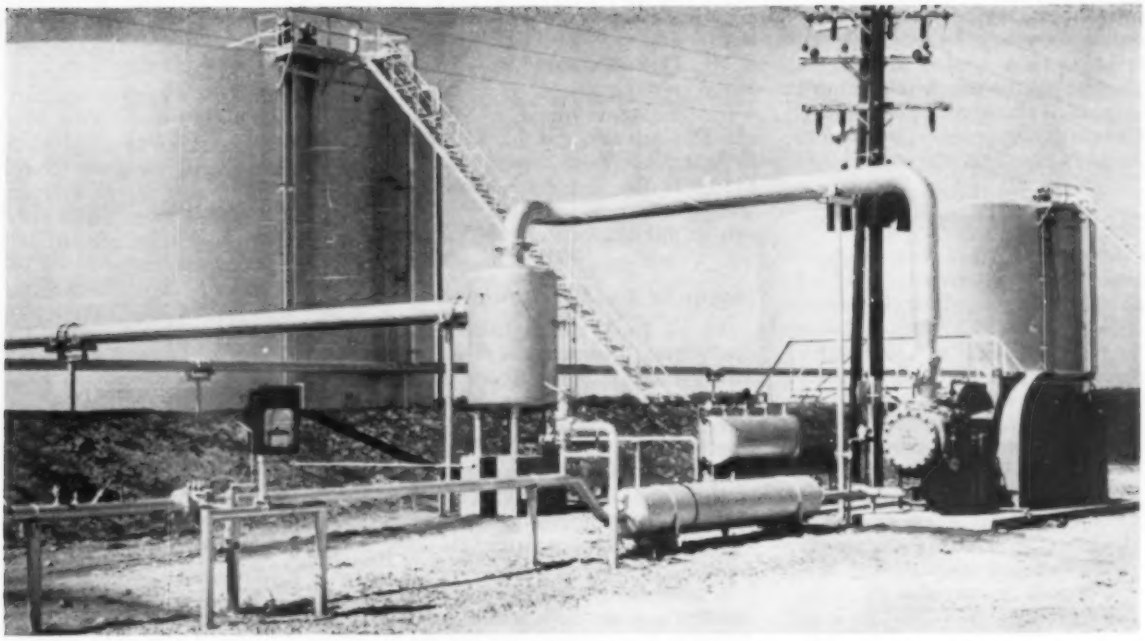


FIG. 1. **Vapor recovery system** at Atlantic's Block 31 field in Crane County, Texas. The single stage, double-acting compressor handles about 700 Mcf per day. The elevated separator is a suction scrubber, and the horizontal vessel on the ground is a pulsation dampner upstream of a meter run.

COULD YOU RECOVER STOCK TANK VAPORS AT A PROFIT?

R. E. WELDON, JR., *The Atlantic Refining Company, Dallas, Texas*

It's being done more and more . . . but, there's plenty of applications still overlooked. Here are some rules of thumb that will help you evaluate your operations . . . with cost figures, recovery data, payout . . . and three field installations

THE RECOVERY of vapors from lease storage tanks can be a profitable venture as well as a conservation measure. Some of the vapor recovery systems installed by southwest producers have paid out in less than a year. However, many vapor recovery applications are being overlooked because of a lack of information on how to recognize these applications. Some of the questions asked are: How do you recover stock tank vapors?; Is there a way I can determine if my lease is applicable?; How much does it cost? and, What about payout?

How It Came About

Our industry long recognized the importance of reducing evaporation loss from crude oil and its products. Much progress has been made toward eliminating these losses through the use of vapor-tight storage tanks, conservation vent valves, and more efficient separation facilities. Some companies have established extensive evaporation-loss-control programs.

With few exceptions, stock-tank vapors are more valuable sold as crude oil than as gas. But after you have done everything you can to reduce the vapor losses from the tank, you will in many cases, still have plenty left over. It is estimated that the gas vented each year from lease storage tanks in this country has a value of about $35 million.

It is profitable to recover tank vapors on many leases. This is a popular subject at this time, and there has been a good deal of attention given to the design and equipment aspect of vapor recovery. However, there is very little information available on how to recognize where it is profitable to recover tank vapors.

The recovery of vapors from lease storage tanks has been practiced in California for many years. It has been only within the last 5 or 6 years that producers in the Southwest have been recovering tank vapors for injection into gasoline plant gathering systems. Most of these installations have been on large tank batteries where the production was over 500 bbl per day. Many of these vapor recovery systems have shown a payout in less than a year. Two of the systems that we installed paid out in less than three months.

The present trend toward consolidation of lease storage facilities for lease automatic custody transfer (LACT), automation, and unitization insures a bright future for tank vapor recovery. The storage of large volumes of oil at one location usually means that it will be profitable to recover vapors. How-

Based on a paper presented by the author before the Southwest District API at Albuquerque, New Mexico, March 22-24, 1961.

ever, vapor recovery is not necessarily limited to these large batteries. We believe that in many cases it can be profitably applied on batteries where the producing rate is as low as 200 bbl per day and where gravity of the oil is in excess of 35 deg API.

THREE ATLANTIC INSTALLATIONS

During the last three years, we have installed vapor recovery facilities on three tank batteries whose total production is about 33,500 bbl per day. For a total investment of $50,000, Atlantic and its co-owners are realizing a net income of about $360,000 per year by recovering vapors that had previously been vented. Needless to say, this has spurred our efforts to find more application for vapor recovery. Two of these projects are of unusual magnitude and not ordinarily found in the field. They do demonstrate the relative economic importance of vapor recovery.

Block 31 Field in West Texas

All Devonian production from the unitized Block 31 field in West Texas is gathered from separation stations to a central battery consisting of four 20,000-bbl tanks. Oil enters the gathering system from treaters operating at 20 to 25 psig and 150 F. The central battery handles 15,000 bbl of oil per day having a gravity of 47 deg API.

A stock-tank vapor gathering system was installed on this battery in 1958. The vapors are compressed to about 25 psig and injected into our Block 31 gasoline plant gathering system. The vapor recovery system shown in Fig. 1 cost about $30,000 and paid out in two months.

In 1959, we recovered an average of 686 Mcf per day, and the net income to Atlantic and its co-owners was about $230,000. This includes both the lease and plant income since the plant is a part of the unit.

Magnolia Field in Arkansas

All oil from this unitized field is brought to a central point for sale through LACT units. Oil is separated at four test stations and gathered to the central facilities. Here, the oil from each station flows through a separator operating at about 15 psig, after which it is dumped to a 20,000-bbl surge tank. Daily production to this tank is 17,500 bbl of 40 deg API oil.

A tank vapor recovery system was installed in conjunction with the central facilities. Tank vapors are compressed to about 15 psig, after which they are combined with the 15-psig separator gas and compressed to about 100 psig for injection into a gasoline plant gathering system. The vapor recovery system cost about $15,000 and is recovering about 700 Mcf per day.

This system has been in operation some nine months at this writing. Based on performance so far, we estimate that the net yearly income to the unit will be about $125,000. The unit gets 60% of the liquids recovered by the gasoline plant plus the income from sale of residue gas. The Magnolia vapor recovery compressor is shown in Fig. 2.

State "T" Lease, New Mexico

The vapor recovery system on the State "T" Lease in the Denton field, New Mexico, is much smaller than the two described above. This system gathers vapors from two tank batteries and commingles them for compression to 15-20 psig for delivery to the Denton Gasoline Plant. These batteries are side by side. One consists of five 1000-bbl tanks and a 1500-bbl power oil tank handling Devonian production. The other includes three 1000-bbl tanks and a 1500-bbl power oil tank handling Wolfcamp production.

All tanks are manifolded together into a common vapor gathering system. Total production to these two batteries is about 1100 bbl per day. Oil gravity averages around 45 deg API. Oil flows through heater-treaters operating at about 15 psig and 110 F prior to storage in the tanks.

This system cost $4700 and has been in operation only about four months at this writing. It recovers about 40 Mcf per day. We estimate that our net income from this system will be from $8000 to $10,000 per year. This includes the lease income plus our share of the gasoline plant income, which is about 19%. This system is shown in Fig. 3.

WHAT'S IN IT FOR YOU

These examples show that a substantial income can be realized from the sale of tank vapors. There are other benefits to be realized that are often overlooked and on which it is difficult to place a monetary value. A properly designed system prevents air from entering the tanks, thus eliminating or

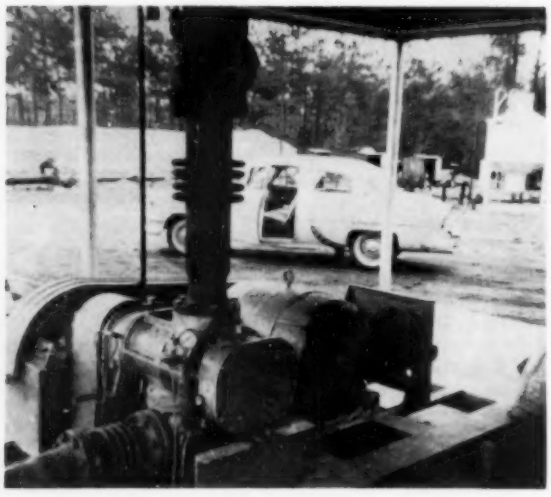


FIG. 2. **First axial-flow compressor** on a vapor recovery system was installed in the Magnolia field of southern Arkansas. This system handles about 700 Mcf per day. The electric motor is rated at 40 hp at 1200 rpm and 60 hp at 1800 rpm.

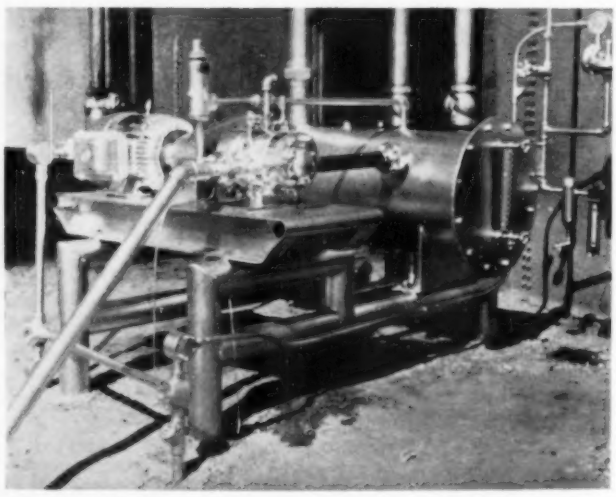


FIG. 3. **Small vapor recovery system** on Atlantic's State "T" lease in the Denton field of Lea County, New Mexico, serves ten stock tanks in two parallel batteries through a common manifold. This unit has a capacity of about 50 Mcf per day. Horizonal separator in background is a suction scrubber.

greatly reducing tank corrosion. Fire and explosion hazards are reduced also. All Atlantic's systems have gas blanketing facilities which prevent air from entering the tanks during normal operation. Safety to operating personnel is also a big benefit to be realized from vapor recovery. This is especially true in fields such as Magnolia where sour gas is produced. Coupled with ground-level tank gauges and LACT facilities, this tank vapor recovery system practically eliminates the sour gas hazard.

The Block 31 and the Magnolia vapor recovery systems were brought about as the result of tank battery consolidation. In neither case, however, was tank vapor recovery used to justify battery consolidation. This additional justification was not needed for these two projects, but had either of these been economically borderline cases, the additional income from vapor recovery would have made a big difference in the economics of the overall project. When considering projects involving consolidation of tank batteries, you should be careful not to overlook tank vapor recovery possibilities.

HOW TO RECOGNIZE POTENTIAL APPLICATIONS

A good question here is, "How does one recognize an application where vapor recovery can be economically applied?" Here is a list of questions to be answered that will help determine which tank batteries are potential applications for vapor recovery.

1. Is there a market for low-pressure gas?
2. How much gas is being vented?
3. What is the value of this gas?
4. What will it cost to deliver this gas to market?

Low Pressure Gas Market

Unless a large volume of tank vapors is available, the gas market should be a gasoline plant or similar hydrocarbon recovery plant where payment depends on the value of the liquids recovered. Most leases meet this requirement where separator gas is sold to gasoline plants under a casinghead gas contract. Most of these markets have delivery pressures less than 50 psig. In some cases, delivery pressure is higher than separator pressure and the separator gas has to be compressed to sales line pressure. These compressors will usually have enough additional capacity to handle tank vapors boosted to their suction pressure by a vapor recovery compressor.

Volume of Tank Vapors Being Vented

It is difficult to arrive at a rule-of-thumb that can be used to estimate the volume of gas being vented from a particular tank battery. There are many factors that affect this, but probably the most important are: (1) operating pressure of the separator or treater dumping into the tank; and, (2) gravity of the oil.

You can get a rough estimate from Fig. 4 of the volume of gas that will be evolved per barrel of oil knowing the separator pressure and stock-tank oil gravity. This curve is based on flash data from laboratory studies of various crudes and on a few actual field measurement tests. The curve should not be used as a substitute for actual measurement of gas in the evaluation and design of a particular vapor recovery system. It is helpful in recognizing which of your batteries are potential vapor recovery applications.

A look at the actual gas-oil-ratio data from our existing vapor recovery units will also be helpful in predicting the volume of gas being vented from lease tanks. Table 1 is a summary of these data. Separation conditions are for the separator or treater dumping into stock tanks. Gas-oil ratios are standard cubic feet of tank vapor recovered per barrel of oil produced. The Block 31 gas-oil ratio is the average for the year 1959. The Magnolia gas-oil ratio was measured in January 1961 and may be a little low as a yearly

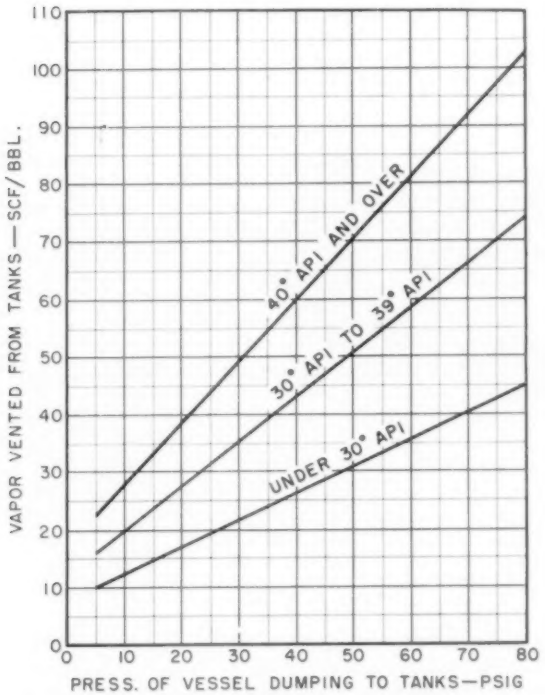


FIG. 4. **Volume of vapor vented** from stock tanks can be roughly estimated from this correlation.

TABLE 1. Gas-Oil Ratio Data from Atlantic Vapor Recovery Systems.

System	Separation Conditions* Pressure psig	Temperature F	Stock Tank Oil Gravity deg API	GOR Scf per Bbl
Block 31	20	150	47	45
Magnolia	15	75	40	38
State "T"	15	110	45	35

*Separator or treater dumping to the tank.

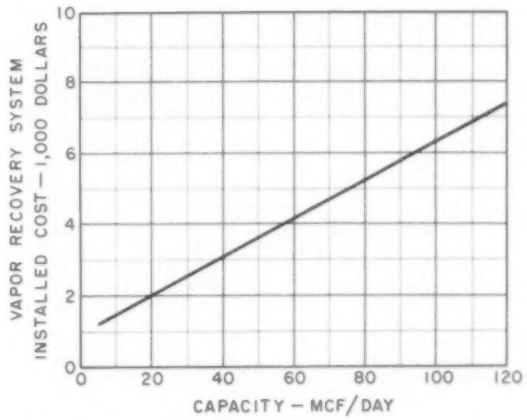


FIG. 5. **Approximate cost** of a vapor recovery system varies with capacity. This curve is based on discharge pressures up to 25 psig.

average. The State "T" gas-oil ratio was also measured during January 1961. We expect the gas-oil ratio on the State "T" to average from 45 to 50 std cu ft per bbl over a year's operation.

How Much Are Tank Vapors Worth?

The value of these vapors is dependent on their GPM (gallons per thousand cu ft), gasoline plant efficiency, price of liquid products recovered, and terms of the casinghead gas contract. As a rule-of-thumb for the rough economics to determine potential applications, a net value of $0.35 per Mcf can be used. This is the net income to the lease. Where the producer owns a share of the gasoline plant, the income per Mcf would, of course, be higher.

Cost of Vapor Recovery Systems

There are many factors that affect the cost of the equipment required to recover stock-tank vapors: sales line pressure, volume of gas, number of tanks in a battery, type of compressor, type of compressor drive and degree of automation, to name a few. Fig. 5 gives the approximate cost of small vapor recovery systems as a function of gas rates for discharge pressures up to about 25 psig. This can be used as a rule-of-thumb cost.

HOW TO EVALUATE A SPECIFIC APPLICATION

By applying these rules-of-thumb, the producer can determine which batteries are the best prospects for tank vapor recovery. To evaluate one of these prospects, it is necessary to take the following steps:

1. Measure the volume of tank vapors being vented.
2. Measure the GPM.
3. Figure the economics.

Gas Measurement

An orifice well tester and a recording manometer can be used to measure the gas vented from a tank battery. The pressure recorder should have a small range since the differential to be measured is very low. A range of 0-5-in. of water is well suited for this application. The orifice well tester usually can be installed in the tank battery vent line. Pressure on the tank can be controlled by the size of plate installed in the orifice well tester. In order to get a representative test, the pressure should be about the same as it would be with the vapor recovery system. This will usually be from 1 to 3 in. of water.

Prior to the measurement test, all tanks should be checked for leaks, and any leaks should be repaired. Operating conditions of the lease separation equipment and the producing rate should be set as close to normal as possible. The test should be conducted for several days in order to get some idea of the variation in flow rate with temperature, liquid level in the tank, filling and emptying cycles, and weathering time. The specific gravity of the vapors should be measured as often as possible throughout the test. The gravity will vary considerably with liquid surface temperature, and gravity measurements should be made both during the day and night to arrive at a good average. For most accurate results, temperature of the gas flowing through the orifice should be continuously recorded.

Our experience indicates that the volume of gas obtained with a vapor recovery system has been consistently higher than was measured with the orifice well tester. This has varied from 1.3 to 1.6 times as high as was predicted. Other operators have reported similar experiences. The magnitude of this variation depends on when the test is conducted. The difference will be greater where a test is run during the winter months than if the test is run during the summer, when compared with the average daily volume of vapors recovered throughout the year with a vapor recovery system.

Fig. 6 gives the month-to-month variation in the stock-tank gas-oil ratio at Block 31. The average GOR for the year was 43 std cu ft per bbl. When we measured the gas to evaluate the economics of vapor recovery, we obtained a gas-oil ratio of 29 std cu ft per bbl. The test was run during the month of June. If it had been run during the winter, the difference between the predicted and actual gas-oil ratio would have probably been greater.

The economic and design calculations should be based on higher gas volumes than are actually measured. To calculate yearly income, the average gas rate measured should be multiplied by 1.3 if the measurement test is conducted during the summer months, and 1.5 for winter tests. As a rule-of-thumb, the gas rate obtained during the test might be doubled for equipment design purposes.

Tank Vapor GPM

The price received from gas sales under most casinghead gas contracts is based on the liquid content of the gas. The GPM of stock-tank vapors is very high and will often be 4 to 5 times as rich as separator or treater gas. The compression test GPM is probably the most common basis on which gasoline plants allocate liquid products. Some plants allocate on a charcoal GPM or on a GPM as calculated from a gas analysis. Regardless of which method is used, it is important to get an accurate measurement of the GPM in order to evaluate the economics of recovering tank vapors. The GPM test can be run during the time the gas is being measured. Several tests should be run to get a representative GPM for this period.

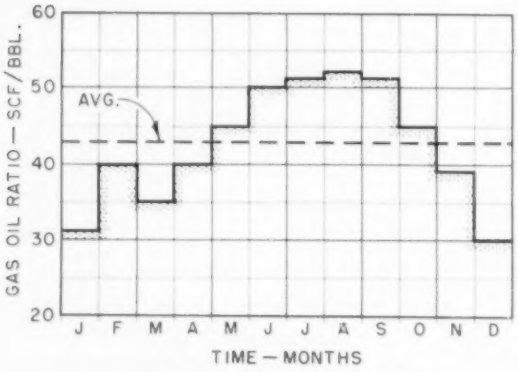


FIG. 6. **Monthly gas-oil ratio variations** for Atlantic's Block 31 vapor recovery system.

TABLE 2. GPM of Stock Tank Vapors.

Component	Magnolia	Block 31	State "T"
Propane	8.48	10.26	6.50
i-Butane	2.07	1.73	2.01
n-Butane	4.39	6.82	4.68
i-Pentane	1.38	1.37	1.36
n-Pentane	1.27	1.88	1.28
Hexanes	.49	1.84*	.61
Heptanes Plus	.84	—	.30
Total GPM	18.92	23.90	16.74
Gas Specific Gravity	1.53	1.70	1.40
Oil Gravity deg API	40	47	45
Month GPM Measured	September	June	January

*Hexanes plus.

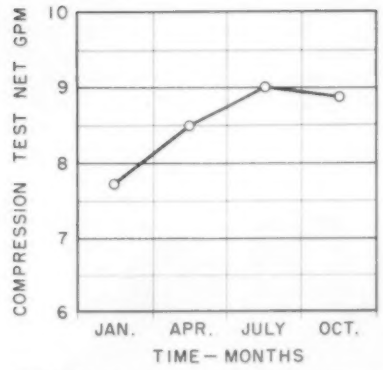


FIG. 7. **GPM content in stock tank vapors** will vary with surface temperature. This curve shows the variation in quarterly compression test net GPM for the Block 31 system.

The GPM of tank vapors will vary considerably with the temperature of the liquid surface in the tank. Depending on what time of the year the test is made, the measured GPM should be adjusted up or down to arrive at a yearly average. Fig. 7 gives the variation in compression test net GPM throughout the year at Block 31. This variation is from a minimum GPM of 7.75 in January to a maximum GPM of 9.0 in July. This curve can be used as a guide for adjusting the GPM determined during the measurement test to obtain a more realistic average for the year.

Table 2 gives the GPM's of several tank vapors as calculated from gas analyses. For comparison, the compression test net GPM corresponding to the Block 31 analysis is about 8.75. There is considerable variation in these GPM's and you can not necessarily correlate tank vapor GPM with oil gravity. Even if all these samples had been taken under the same atmospheric conditions, there could still be considerable variation in GPM. For example, a sample of tank vapors taken in December off a 38 deg API crude had a propane plus GPM of 21.8. At another battery, during the summer, the vapor off a 42 deg API crude had a propane plus GPM of 23.8. These GPM's are higher than would have been predicted from the data given in Table 2. This points out the importance of measuring the tank vapor GPM on each battery you evaluate.

Figuring Economics

With the volume and GPM data as determined from the testing program, income from the sale of tank vapors can be determined by referring to the casinghead gas contract serving the lease. Applicable royalty, taxes, and operating costs should be deducted to determine the net income. Any benefits, such as personnel safety and reduction in tank corrosion, should be included also in the justification where applicable.

An estimate of the cost of a skid-mounted, vapor recovery unit can be obtained from one of the manufacturers of this type of equipment. These packaged units are complete in that they normally only require connecting to the suction, discharge, and power source. Any other equipment needed to adapt the tank battery for vapor recovery and the labor required for installation will have to be added to the cost of the packaged unit to obtain a total installation cost. With these data, the producer can then determine if it is profitable to install a vapor recovery system on this battery. ★ ★ ★

ABOUT THE AUTHOR

R. E. Weldon, Jr. is a member of the Atlantic Refining Company's Production Engineering Group. He obtained a BS degree in chemical engineering from Louisiana Tech in 1950, after which he spent two years in the Army. He joined Atlantic in 1953 and was assigned to the Chemical Engineering Group in Dallas. In 1956 he went to Longview, Texas as a production engineer in Atlantic's East Texas District. He was assigned to his present position in 1958 and has worked primarily with lease processing operations. He is a member of the Society of Petroleum Engineers of AIME.

API's Mid-Continent District Elects New Officers

New officers of the Mid-Continent District of the American Petroleum Institute's Division of Production were elected at the district meeting which attracted nearly 600 oil men to Tulsa on April 5-7. Chosen district chairman was R. C. Earlougher, Earlougher Engineering, Tulsa (third from left). Other officers are (left to right): E. B. Krider, National Cooperative Refinery Association, Great Bend, Kansas, vice president for Kansas; Warren Richardson, Cameron Oil Company, Oklahoma City, vice chairman for the Oklahoma City area; Earlougher; Homer Austin, Phillips Petroleum Company, Pauls Valley, Oklahoma, vice chairman for the Golden Trend area; R. J. Hall, Liberty Manufacturing Company, Oklahoma City, district secretary-treasurer; John D. Albright, Cities Service Petroleum Company, Bartlesville, chairman of the District Advisory Committee; W. S. McCuen, Samedan Oil Corporation, Ardmore, Oklahoma, vice chairman for the Arbuckle area; W. H. McPhail, Tidewater Oil Company, Drumright, vice chairman for the Drumright area; and W. R. Cook, Duncan independent, vice chairman for southwestern Oklahoma. Not pictured are James Austin, Austin Drilling Company, Seminole, vice chairman for the Seminole area, and Max A. Bolick, Cities Service Petroleum Company, Pampa, vice chairman for the Texas Panhandle area.

Experienced engineers evaluate and operate properties under direction from Hank Gruy, president of the firm. Staff members are, left to right, Steve Dardaganian, reservoir engineer; Forest Garb, reservoir engineer; Gruy; Clarence Netherland, reservoir engineer; Jack Hinckley, engineering-operations manager, and William Horn, accounting and data-processing manager and treasurer.

WHY CONTRACT PROPERTY MANAGEMENT KEEPS GROWING

WALTER A. HOGAN, *Field Editor*

CONTRACT PROPERTY MANAGERS have developed a new concept of operating producing properties that offers limited-scale owners the advantages previously available only to major oil companies. And why shouldn't they? The modern contract managing firm includes qualified staffs of engineering-operating supervisors, reservoir engineers, and accountants using electronic machines.

WHAT THEY OFFER

A look at one of these contract management organizations gives the appearance of an oil company production department: graduate engineers with extensive field experience in their specialties, records produced with electronic machines, complete files showing lease locations and operating data. There's only one main difference — instead of serving a single large owner, these men handle properties for a number of smaller owners to increase operating efficiency.

The basic concept follows the growth of specialized services in every other phase of operations — contract drilling, logging, cementing, supplies, perforating, and others. Contract property management thus becomes another step to free operators from high overhead cost of an efficient technical-operating department.

WHERE DOES IT FIT IN?

This service gives production owners greater flexibility. It allows them to keep properties that previously they would sell as uneconomical to produce.

They can drill in areas without restricting themselves to supervising production there. And it frees them from the routine supervision involved in producing properties, allowing them to pursue their main interests more profitably.

The owners of an old producing property in Southern Oklahoma secured a leading property management firm to represent them at unitization hearings prior to waterflooding.

Unitization plans were later dropped because of disagreement among the owners. However, a study by the firm indicated that one of the wells should be cleaned out and fracture treated.

The property manager was employed to supervise work-over operations at the well. Production increased from 3 bbl per day to 90 bbl per day after recovering load oil.

Several weeks later the owners chose the firm to replace the former operator. The property manager selected a pumper on a part-time basis. This man had considerable previous production experience in the area with an indepen-

dent operator who had sold out to a major company.

The property manager explained the necessity for cost-consciousness to do an effective job, then he worked out a routine for operating the property.

This unallocated well still produces 31 bbl per day, six months after the workover. Increased income received has been twice the cost of working over the well, and it still produces an additional 28 bbl per day. Production costs since changing operators, including supervision and overhead, have been less than 28 cents per bbl for this old lease.

If a producer doesn't own or control sufficient working interest to be able to choose the operator, he may employ a contract manager to check operating details, and advise him in matters affecting his interests. This relatively inexpensive service assures the owner of correct billing for operating, development and overhead charges; accurate material transfers; fulfillment of gas purchase agreements; determination that income payments are proper and complete and competent advice concerning participation in drilling, workovers, and other activities recommended by the operator.

In East Texas, an owner who held a non-operating interest wanted his operating costs reviewed. He secured a management firm to investigate and they found that the present operator was billing him for the cost of the salt water disposal but not giving credit for the allowable that his lease earned from salt water disposal.

The property owner filed a claim with the operator, who paid the owner upon learning of his error.

Owners use property management mainly in Texas, Oklahoma, and Kansas. It has grown continually for seven or eight years in these and other areas domestically, but thus far it has not spread into foreign operations. Contract managers supervise both primary and secondary recovery, on unitized or non-unitized leases.

Since property managers only hold their contracts by doing a better job for less money, they must use latest production methods and watch costs closely. They can't succeed, however, if forced by the owner to conform to inefficient and wasteful practices.

Property managers believe that some false ideas prevail in operating properties. They don't feel that one of the joint owners must operate the lease to make it profitable, particularly since many owners don't want production responsibilities with the time and attention required to obtain maximum profits.

Property managers don't believe that operations must cost more in areas of higher production than in stripper fields. They feel that the reverse should hold true since marginal wells cause more trouble as their older equipment breaks down. They find that overhead charges for deep wells need not necessarily be more than for a shallow one.

HOW ONE FIRM OPERATES

Petroleum Property Management, Inc., of Dallas, provides a combination of services including engineering-operating supervision, reservoir analysis, and electronic accounting. H. J. "Hank" Gruy, president, first began a reservoir engineering company, then an oil field accounting company, and finally added the engineering-operating company. He supervises and coordinates these three separate companies to function together. "Property management seemed a rather natural evolution as a service that fits a lot of people's needs", Gruy said.

Engineering-Operating

Let's look first at the engineering-operating phase of Petroleum Property Management, headed by Jack Hinckley, manager and vice president of the firm. He supervises all field operations and personnel.

Hinckley's background in operations began with a BS degree in mechanical engineering from the University of Oklahoma. He started 15 years ago with a major oil company gaining experience on a pulling unit, gasoline plant and a waterflood and dry gas repressuring operation in a large field. He did reservoir engineering and then became a production superintendent.

His experience includes drilling and completing high pressure oil and gas wells for another major oil company, chief engineer for an independent, area exploitation engineer for a large independent supervising waterfloods, evaluating wildcats and most other phases of operations. These duties carried him through most oil areas from Colorado to the Gulf of Mexico.

Last year he assumed his present position with Petroleum Property Management. "We do many of the same things the owner would do to increase production, but we're continually look-

Electronic machines speed processing accounting and administrative records. William Horn and Don Shepherd, tabulating supervisor, pull a lease operating report from an accounting machine.

Basic card-processing set up of accounting and calculating machines handles records usually processed on more complex and costing computers.

ing for better methods," Hinckley emphasized. We employ and properly supervise more-capable workers and instill cost-consciousness into them. Unnecessary work and reports are eliminated. When minor mechanical troubles occur, the field man repairs them but must consult with the manager when major trouble is detected. This reduces delays, lost production, and needless expense in many instances.

"We strive for increased profit on a lease, not just increased production at any cost. We negotiate better rates from well servicing contractors and furnish field supervision at no additional cost above the flat fee agreed upon."

"Our clients have no field office expenses to pay, and keeping paper work to the necessary minimum cuts down administrative costs. This system works well for owners in many areas," he commented.

Details handled include fulfilling regulatory body requirements, periodic well testing, seeking practical changes, and studying each well for additional production possibilities.

The firm also prepares workover recommendations, cost and payout estimates, and directly supervises such remedial work in the field. "Workovers provided enough profit in two instances recently to cover our management fees for years to come," Hinckley said.

Waterflood studies include evaluation of reserves, design and cost of equipment, and treating plant design. Clients receive representation on engineering committees, at state regulatory commission hearings, and at any meeting that pertains to their lease.

How do they take over an operation?

"First we evaluate the manpower presently on the lease," Hinckley said, "and we try to keep the best men within this group, cutting only personnel we consider unnecessary or incompetent. We're primarily interested in securing capable field men to work for us, otherwise we cannot succeed. Sometimes we find field men who have closed minds to new techniques. Others have become inefficient, possibly from being in one place too long."

"In taking a fresh look at an established operation, we sometimes find the present operator making a hard job out of an easy one. Many of these worked-to-death leases don't require the attention they have been receiving. We can reduce costs by putting lease visits on a realistic time schedule. On the other hand, we find many wells which are not receiving enough attention, resulting in too much down time and lost production. Only close checking will determine the correct amount of attention each well requires."

LEASE OPERATING STATEMENT

D. SHEPHERD (LEASE NAME) — 40621 (LEASE NO.) — PETROLEUM PROPERTY MANAGEMENT, INC. (COMPANY) — DEC. (MONTH) — 1959 (YEAR) — ECTOR COUNTY (COUNTY)

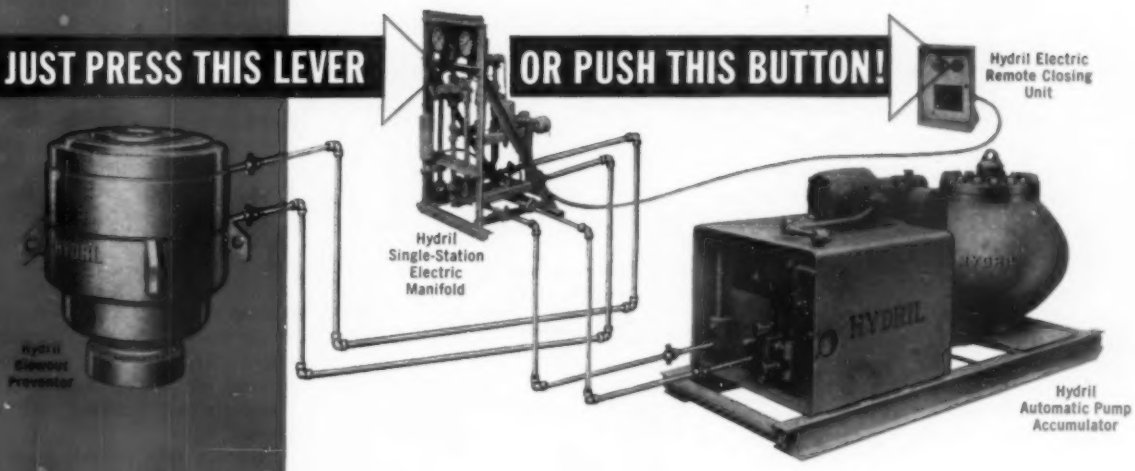
NO. OF WELLS 93 — WORKING INTEREST % .3828400 — INCOME % .34361000

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR TO DATE	CUMULATIVE
GROSS PRODUCTION														
Oil Bbls (A)	41319	36462	41062	37244	38104	34357	32015	31842	30906	31472	30102	32702	417387	7599695
Gas Mcf	197250	197965	179173	242803	144993	212691	192788	194287	179869	176315	179508	162776	2251721	42301971
Distillate Bbls														
COMPANY PRODUCTION														
Oil Bbls	13819	12416	13847	12574	13115	11562	11006	11041	10467	11004	10530	11002	145421	
Gas Mcf	45896	44846	41330	52808	37272	48089	43912	43780	42581	40502	40753	38275	518768	
Distillate Bbls														
GROSS PIPELINE RUNS														
Oil Bbls	40798	41522	36016	39600	38423	41048	34591	31865	32160	30172	30860	29564	426624	
Gas Mcf	197253	197965	179173	242803	144993	212691	192788	194287	179869	176315	179508	162776	2251721	
Distillate Bbls														
COMPANY PIPELINE RUNS														
Oil Bbls (B)	14302	14169	12359	13820	13152	14067	11739	11083	10968	10311	10871	10364	147010	
Gas Mcf (C)	45896	44846	41330	52808	37272	48089	43912	43780	42581	40502	40753	38275	518774	
Distillate Bbls														
COMPANY SALES														
Oil (D)	41335	40069	32919	37271	36046	38396	31847	30002	29682	27922	29514	28611	404617	5410116
Gas (E)	2914	2890	2551	3537	2520	3015	2687	2884	2802	2825	3027	2991	34937	36780
Distillate														
TOTAL	44291	42958	35470	40808	38566	41407	34534	32886	32484	30748	32544	31602	439422	5446905
Less Prod. Taxes	2131	2072	1760	1972	1857	2002	1668	1602	1581	1494	1589	1922	21658	214260
COMPANY INCOME AFTER TAXES (F)	42318	40887	34710	38834	36712	39405	32865	31283	30903	29254	30955	29679	417764	5232632
PRODUCTION EXPENSE B-8														
Payroll labor	3768	3107	3701	3689	4680	4391	4404	3867	2801	3512	3438	3921	45080	
Contract labor	707		852	961	109	2886	440	170	200	214	443	177	6930	
Trucking and hauling	13	458			291	48	117	179	94	32	17	51	948	
Hot oil and paraffin service	592	445	1461	186	70	647	436	270	140	731	562	36	5576	
Well servicing	2701	704	1538	844	1817	4635	3868	1708	262	1168	794	459	20451	
Cleanout and swabbing														
Power and fuel	1873	1321	1381	1177	1139	1089	555	1518	876	956	601	1739	14222	
Repairs	3606	1222	1277	1710	1892	4031	2989	1745	1353	1322	1278	797	23021	
Supplies	141	48	333	70	463	335	35	98	19	583	78	61	2264	
Treating	2330	415	1793	524	52	2023	738	908	268	567	1535	372-	10779	
Auto and truck expense	1594	183	883	744	582	851	821	914	637	880	604	26-	8667	
District expenses	535	785	1173	1029	904	1232	1506	1915	429	1444	1949	1591	14491	
Payroll taxes and insurance	469	394	294	264	30	157	59	23	47	172	1942	193	3985	
Miscellaneous	810	96	184	783	481	299	664	198		263	91	48	3875	
Ad valorem tax	1548									415-		45514	46647	
Office overhead	3241	3265	3265	3265	3265	3215	3240	3215	2715	3213	3716	2535	37950	
TOTAL OPERATING EXPENSE B-8 (G)	23930	12444	17929	15223	15516	25851	18106	16369	9841	14894	16960	57089	244774	2620381
Less Co-owners Share	14310	8002	11163	9149	9292	15149	11632	9953	5694	9354	11702	35195	150439	1628755
COMPANY OPERATING EXPENSE (H)	9622	4442	6769	6076	6222	10682	6474	6414	4148	5733	5260	21871	93711	973616
COMPANY OPERATING PROFIT (F-H)	32698	36446	27942	32759	30488	28723	26392	24869	26755	23514	25693	7808	323672	4259008
LEASE DEVELOPMENT COSTS B-8														
Leasehold Cost								21817				265	22082	313819
Intangible Development & Dry Holes	8421	7300	2021	5407	501	4303	1614	16960	7144	192	515		54375	2253271
Equipment	27386	53944	7615	15559	1794	845	8432	4540			6900		117931	1702362
TOTAL B	35807	61244	9635	20966	2295	5148	10046	34237	7144	192	7200	265	194179	4427124
Less Co-owners Share	27532	53830	6209	16483	2417	4186	7634	24843	5380	160	5957	232	153759	2891338
COMPANY DEVELOPMENT COSTS	8274	7414	3425	4484	1650	962	2612	9393	1763	31	1458	33	40325	1535785
COMPANY'S PAYOUT STATUS														
Balance To Be Recovered														
Profit														2717749
Sales Price Per Bbl-Oil (D ÷ B)	2891	283	266	2745	2745	2735	2715	2715	2715	2715	2715		2795	
Sales Price Per Mcf-Gas (E ÷ C)	65	65	65	75	65	65	65	65	65	75	75		75	
Lifting Cost Per Bbl (G ÷ A)	585	745	445	415	415	795	575	515	325	475	565		595	
Lifting Cost Per Well (G ÷ *)	25731	19381	19278	16369	16684	27775	19469	17601	10982	16015	18237		21933	
Percent Operating Expense To Income (H ÷ F)	2285	1086	1950	1575	1695	2711	1970	2050	1342	1960	1699		2249	

Lease operating statement combines several reports. Each monthly report shows data for all preceding months, then gives year's total to date and cumulative total on lease.

To STOP a blowout

JUST PRESS THIS LEVER **OR PUSH THIS BUTTON!**



THE HYDRIL ENGINEERED

BLOWOUT PREVENTION SYSTEM

You're looking at the most complete and flexible combination of equipment ever offered to control menacing downhole pressures. The Hydril Control Manifold—with hydraulic or electric remote operators—triggers the system from driller's and remote positions, drawing from the Hydril Automatic Pump Accumulator, a self-replenishing powerplant, the power to close the Hydril Blowout Preventer and auxiliary control equipment. This safety system enables all drilling to proceed in confidence that dangerous well pressures are under positive control.

Flexibility of the system enables the operator to choose from a wide range of sizes, types and capacities of Hydril Blowout Preventers, Automatic Pump Accumulators, and Control Manifolds. Accumulators are available for electric or gasoline-engine operation. The Accumulator and control devices can be located at a safe distance from the well, with additional controls, of course, within the driller's reach.

Let your Hydril representative show you how the Hydril Safety System is tailored to fit your well conditions...and how

HYDRIL TAKES THE BLOW OUT OF BLOWOUTS!

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Lafayette
New Iberia

OKLAHOMA
Oklahoma City
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Dallas
Houston
Midland
Odessa

WYOMING
Casper

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HYDRIL COMPANY

714 WEST OLYMPIC BOULEVARD
LOS ANGELES 15, CALIFORNIA
Factories at
Los Angeles and Houston

A routine operating account with a client allows for time spent studying the wells when they first become managers, then keeping close track of operating details. It also includes studies and recommendations for remedial work, secondary recovery, or other plans for increasing net profits.

When working over, or drilling and completing a well becomes necessary, they generally charge for time on a flat fee basis or daily rate. The routine operating account usually includes charges for supervisory visits to the lease.

Reservoir Evaluation

Where do evaluation studies fit in?

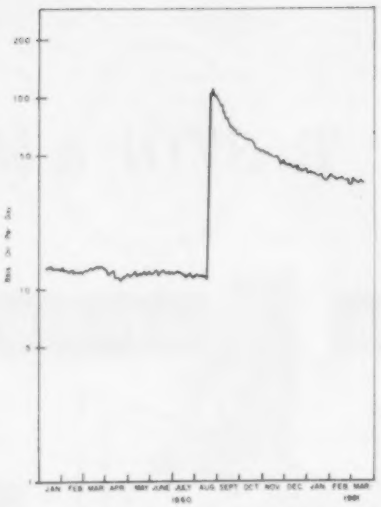
Clarence Netherland, who manages the evaluation company and holds the position of executive vice president, said "Our first step in evaluating a property is to get back to fundamentals — find out how much oil the reservoir contains and what mechanisms provide the energy drive. This includes studying reservoir rock and fluid characteristics to predict the performance and problems which may occur. From this analysis of the producing reservoir, it is possible to determine proper completion techniques, type and size of production equipment, and the rates of production which will result in a maximum economic recovery of oil and gas. Our engineering specialists know gas production, also. They predict gas reservoir performance, including the deliverability of each well and their relationship to each other."

After the company geologist defines the original reservoir, the engineers determine whether or not there's a water level moving up or a gas cap expanding. This can help prevent trouble from coning gas or water into the well.

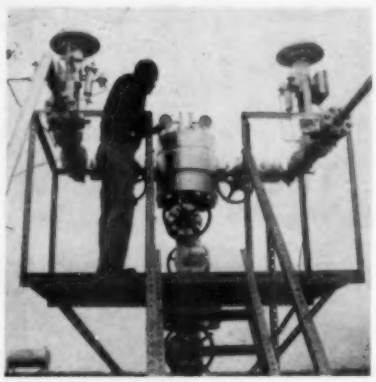
Their reservoir engineers use electronic computing machines to predict reservoir performance. "It's necessary to know engineering and field operations to fully utilize computers," Netherland said, "reservoir specialists can't communicate adequately with a machine operator unfamiliar with their terms."

"Our men have programmed studies of reservoirs which include gas cap expansion and partial water drive as well as regular solution gas depletion mechanics," Netherland said. "Also, we have calculated the performance of gas reservoirs to give the future deliverability of all the wells. Some of these calculations employed the most advanced electronic computers."

The evaluation firm's staff includes six reservoir engineers. Two of these learned electronic computer operation through a manufacturer's school, and one of these men also qualified in log analysis from an advanced, privately-



Working over one well on a marginal lease boosted production for this lease from 11 bbl per day to over 100 bbl per day. Production continues at a considerably increased level.



Property Manager Jack Hinckley checks over dual gas completion.

instructed school. There's one geologist, a draftsman to prepare and post lease maps, and several clerks and secretaries to help with the paper work.

"Clients receive the services of highly-trained specialists for only the amount of time they actually need them," Netherland said, "without their maintaining a full-time staff."

Electronic Records — Keeping

William Horn handles the data processing organization with 13 accountants who operate electronic machines. They use 27 individual accounting and calculating machines, all purchased or leased, and the necessary basic peripheral machines. Total cost of this equipment amounts to over $500,000 and Horn will soon lease an additional electronic computer.

These men-with-machines handle dozens of reports during a month for each client. They keep complete accounting journals, all types of trial balances, accounts receivable, and various other monthly records.

Mainly they dispense royalties and bill joint-owners for expenses on properties they operate, both involving detailed reports.

Horn's group automatically prepares and renders outside billings in processing general accounting, something not too often done with machines. They automatically pull items for billing and dispense checks, which eliminates hand-pulling these amounts and preparing them.

Often owners receive manually-prepared accounting records three months after the transaction actually took place. Accountants using machines complete their records on the 10 and 15 following end-of-the-month closing. "It takes one-fourth the personnel to handle the work," Horn said.

After making an initial trip to study a client's needs, Horn tailors his already set-up procedures to fit. Then they process duplicate copies of all transactions to keep current records. This gives a complete accounting and records service.

Records kept include total production on the lease, broken down by oil, gas and condensate; total income for each month on the owner's portion of production less royalty interests; expenses incurred on each lease, broken down by the type of expense; and cumulative statements of oil, gas and condensate production. Machines automatically produce checks or statements when needed.

"It's easier to audit the machine-kept record," Horn said, "and we can produce an expense sub-ledger and other records as by-products. This includes special reports, and summaries of groups of properties for top management."

The property owner sets up a drawing account to just cover monthly operating costs. He receives a summary of monthly expenses paid, and then adds funds to this account. All large expenditures are submitted to the owner for approval before being incurred.

Why Managers Will Stay

Contract management should keep growing since it has provided increased operating profits with fewer worries on many properties. Owners will find more highly-trained and experienced property managers available than they have in the past. Some of these managers offer personnel and facilities on a part-time basis that owners couldn't duplicate without heavy expenses.

They previously operated only smaller operations. However, increased interest among owners indicates that this same concept should also apply to larger operations in the future. ★ ★

Number 5 of a Series
TELL THIS PETROLEUM INDUSTRY FACT TO YOUR NEIGHBOR

No bargains in this basement!

Drill bits are already digging four miles into the ground, but there are no bargains to be found this deep in the earth's "basement." The average cost of drilling a 5,000 foot well is $50,000. A well three times as deep costs more than *fifteen* times as much — $765,000.

For every nine wells drilled in search of new reserves, only *one* is productive . . . and that *one* is not always profitable. Why, then, drill wells when the risk of failure is so great and the cost so high? Because, for each barrel of oil that is produced another must be found to take its place. *No other industry has as high a raw material replacement cost.* The petroleum industry's need for incentive to drill for replacement reserves has long been recognized by Congress. Any reduction in percentage depletion can only result in higher consumer costs for gasoline and oil if the industry is to continue to supply our country's needs.

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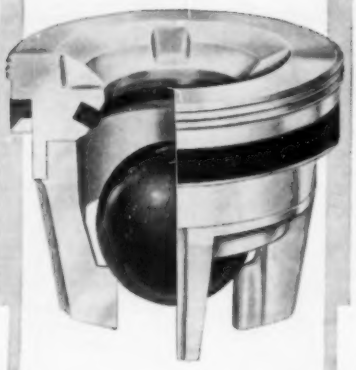
6104

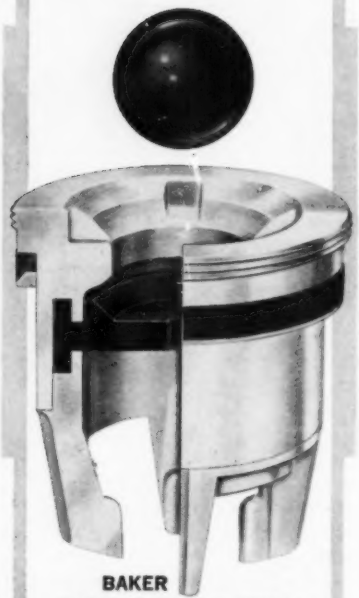
NEW FROM BAKER! TWO INSERT VALVES THAT CONVERT CASING COUPLINGS TO FLOAT OR FILL-UP COLLARS



BAKER INSERT FLOAT-CHECK VALVE

PRODUCT NO. 176

Replaces a conventional float collar in wells of moderate depth. Constructed entirely of aluminum, plastic and rubber for ready drillability, it features the famous Baker "floating ball" that has successfully landed and cemented more strings of casing than any other type of back-pressure cementing valve.



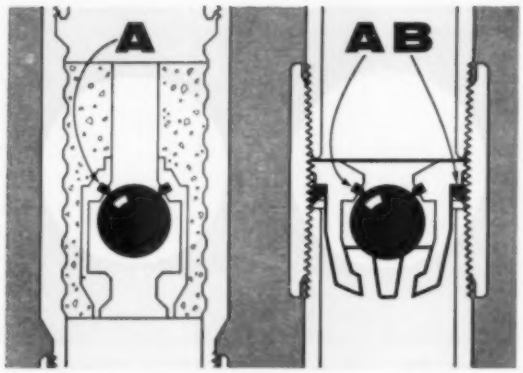
BAKER INSERT FLEXIFILL VALVE

PRODUCT NO. 177

Incorporates the ingenious automatic diaphragm found in the popular Baker Flexiflow collar. This variable valve provides controlled fill-up, for maximum relief from pressure surges during running in. Competitive insert fill-up valves do not provide the obvious advantages of the Baker variable orifice.

Important new design features bring improved performance to insert equipment!

In wells of moderate depth these new insert valves offer convenience and economy. They provide many of the features that have made Baker floating and fill-up equipment so dependable and so widely accepted. Extensive testing by Baker engineers revealed that insert equipment must overcome several inherent difficulties if it is to perform effectively. These tests further indicated that valves already on the market did not adequately cope with the problems. How Baker engineers successfully designed these new insert valves to overcome these problems, and to deliver superior performance, is described below.

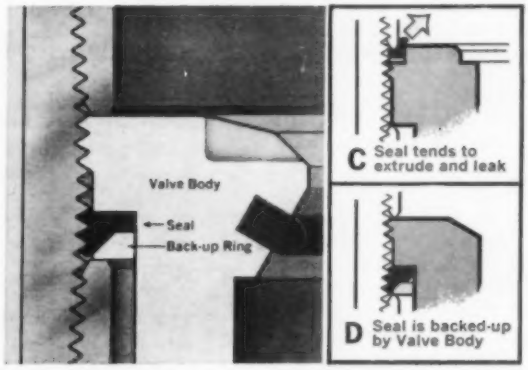


MUST HOLD PRESSURE AT TWO POINTS

In a conventional Baker collar the valve is surrounded by drillable concrete which not only holds the valve in place, but also blocks fluid passage around the outside of the valve. The ball-check valve (Seal A) is thus the only seal required. An Insert Valve, however, does not have this concrete back-up and must provide, in a *one-inch space* (Seal B), all the resistance to pressure provided by a *foot of concrete* in conventional equipment. And, since the pressures involved can reach several thousand p.s.i., the proper location and design of this seal are of vital importance.

WHY LOCATION OF THE SEAL IS IMPORTANT

A seal so located that it relies upon the pin above it for a back-up is not going to be able to stand pressures from below—especially in lighter-weight casing. Drawing "C," below, indicates the way such a seal may extrude and leak. Only a seal located so that it is backed-up by the metal of the valve itself can have a chance of staying on through completion of the job (Drawing "D").

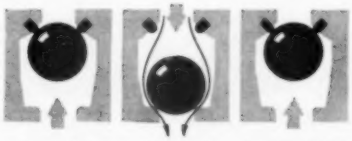


WHY DESIGN OF THE SEAL IS IMPORTANT

Exhaustive testing proved to our engineers that even a seal properly located won't last through the job unless it is designed like the one illustrated above. Notice that the underside of the seal is tapered and that it is *backed-up by a metal ring with a matching taper.* This is important for two reasons: 1) It bottles up the seal to make it effective not only against back-pressure, but also against pressure from above when a follow plug is bumped; and, 2) since the distance between made-up pin ends varies, it lets the valve seal-off in the widest possible range of casing weights without interfering with complete joint make-up.

CONSULT YOUR BAKER REPRESENTATIVE

He will gladly explain the important differences in available insert equipment, and provide you with practical information on its use in your specific well program.



The Floating Ball is the ideal check valve

Running-in: Floating ball maintains a leak-proof back-pressure seal. No springs, guides or hinges. Cementing: Ball is never stationary long enough to be eroded or cut by slurry. After cementing: Ball floats up to reseal the instant pumping stops.

How Variable Valve controls casing fill-up

Running-in: Opening in the diaphragm responds to pressure changes, giving automatic control of fill and maximum relief from pressure surges. Circulate: As desired. Valve Actuated: By pumping ball through diaphragm to provide check valve.

BAKER

BAKER OIL TOOLS, INC.
HOUSTON
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PACK-OFF ASSEMBLY CUTS GAS-LIFT INSTALLATION COSTS

KERMIT E. BROWN, *University of Texas, Austin, Texas*
ROBERT W. DONALDSON, *The California Company, Venice, Louisiana*
CARLOS CANALIZO, *Otis Engineering Corp., Dallas, Texas*

THE COST OF PULLING and rerunning tubing is often the most expensive operation in the installation of gas lift equipment. However, this expense can be eliminated in many installations with the use of a new pack-off gas lift assembly which is installed, and can be retrieved, completely with a wireline unit.

There are several instances in which pulling tubing is either prohibitively expensive or impractical. Most wells located offshore are not readily accessible for workover units to rig up at a moderate cost. The cost to rig up and pull tubing from a multiple-string completion can be excessive even if the well is on a favorable land location, and damage to the producing zones is always possible.

Many wells, both single and multiple completions, must be loaded with a kill fluid prior to pulling tubing. This fluid in many instances can be expected to create a certain amount of formation damage, often to the point that it is entirely impractical to pull the tubing.

Also, many wells simply do not have sufficient reserves to justify a workover even though the installation of gas-lift equipment would increase ultimate recovery from the well.

The first application of the pack-off gas-lift assembly was in an offshore well in Louisiana. The technique consisted of installing a concentric gas-lift valve inside the tubing string on an upper and lower pack-off assembly. The tubing string had been previously perforated mechanically so that the pack-offs could straddle the perforation. Gas was then introduced through the perforated tubing and through the gas-lift valve into the tubing. This unique technique resulted in notable savings for the operator.

Gas-lift Assembly

All equipment is installed by a wire line unit and is thereby retrievable by wire line units. From bottom to top in Fig. 1, it is noted that a full opening bottom collar stop, bottom pack-off, concentric gas lift valve, top pack-off, and top tubing stop are located in that order. The collar stop used in this installation offers a 1 1/16-in. ID for 2-in. tubing and a 1½-in. ID for 2½-in. tubing, thereby allowing passage of recently developed small recording pressure gages and paraffin tools.

The lower collar stop is set with one wire line trip, the tubing is mechanically perforated, and then the entire upper assembly including bottom pack-off, gas lift valve, upper pack-off, and upper tubing stop is run and set with one wire line trip. All equipment is designed to obtain maximum opening through the assembly including stop, pack-offs, and the gas lift valve; however, an outside mounted gas lift valve can be utilized by concaving the gas lift mandrel (Fig. 2). Of course, this restricts the tubing which in turn decreases total fluid production and prohibits the running of pressure surveys and paraffin tools. Table 1 shows the sizes of the various pieces of equipment.

Pack-off Assembly Spacing

Spacing of the pack-offs is determined by standard gas lift spacing procedures. For a one-valve installation, and if the static fluid level is near the surface, the pack-off is spaced by dividing available injection gas pressure by the static gradient of the fluid. This allows maximum distance in spacing, assuming that flow could be started against atmospheric pressure at the surface. If flow has to be started against back pressure, this has to be accounted for in the spacing. Deeper spacing is satisfactory if swabbing is utilized to start the well. However, swabbing may then be necessary every time the well must be kicked off again.

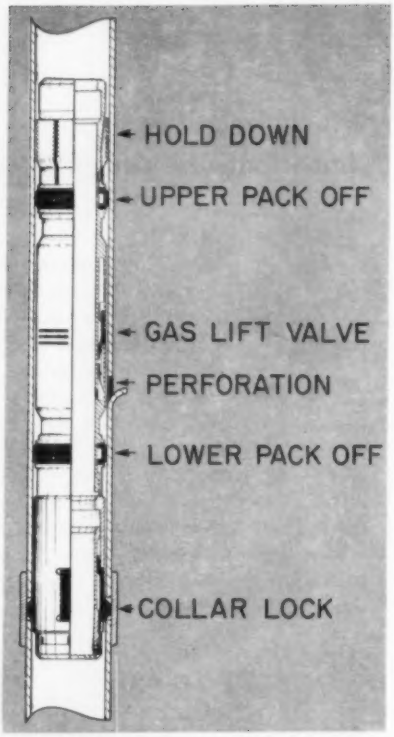


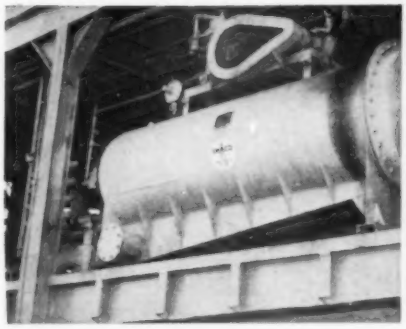
FIG. 1. Complete pack-off gas-lift assembly consists of a lower collar lock, lower pack-off, gas-lift valve, upper pack-off, and upper hold-down. Gas enters tubing through mechanically punched perforation.

If the static fluid level is deeper in feet than the available injection gas pressure divided by the static fluid gradient, the top pack-off can be spaced slightly below the static fluid level. This point is determined by calculating the annular fluid displacement into the tubing, so that the resulting hydrostatic pressure of the head in the tubing is less than the injection gas pressure at that pressure point.

Spacing of additional pack-offs down the tubing string should be handled by known accepted spacing procedures. The additional pressure drop and/or friction loss across each pack-off has been measured, for a maximum of 7 psi for each pack-off at 650 bbl per day. Therefore, spacing procedures as used for the full opening tubing in place should not be altered appreciably. Fig. 3 shows a typical 5-valve installation for 2-in. tubing to handle 600 bbl per day. As a precaution, the pack-offs should not be spaced further apart than normal valve spacings would indicate.

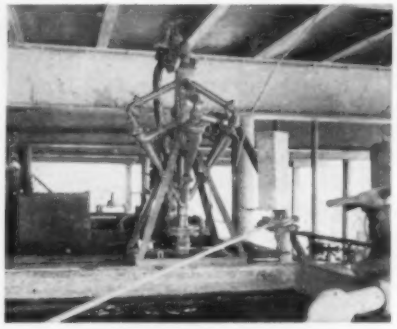
Three good ways to cut drilling costs

The three units shown here are important items behind the recent revolution in drilling fluids that has done so much to speed drilling and cut costs. Each is designed for a different problem but all are efficient and economical. Equally important, all are handled by SWACO -- the leader in mud-treating equipment.



SWACO D-GASSER®

Operators frequently report saving the entire rental cost of a D-Gasser on a well in less than a day.
When mud is gas-cut, the D-Gasser saves money in many ways. It cuts time lost for circulating after trips. It reduces barite costs, it minimizes lost circulation costs and problems. It maintains mud pump efficiency and it actually makes possible the close control of mud weight and viscosity that results in faster drilling with increased safety.



CLAYJECTOR®

If you are using mud as heavy as 12 pounds per gallon, you can cut mud costs and increase drilling rate by using a Clayjector. This is a cyclone-type separation unit that is extremely effective at rejecting unwanted clays and retaining expensive barite.
In addition, since it makes possible the economical maintenance of a low-solids, low-viscosity mud, it actually permits a reduction in bit costs and drilling time.

D-SANDER®

The D-Sander greatly increases the life of mud pump parts and bits when sand or abrasive shale is being drilled. Since it removes virtually all sand-sized solids from the mud, excessive pump-parts and bit-nozzle wear — as well as many other problems — are avoided when a D-Sander is used. There is a size and type to fit every rig and drilling condition.

These descriptions tell just a few of the many ways you can cut costs by mechanical mud treating. For the full story on how you can profit, call your nearest SWACO representative or write us direct.

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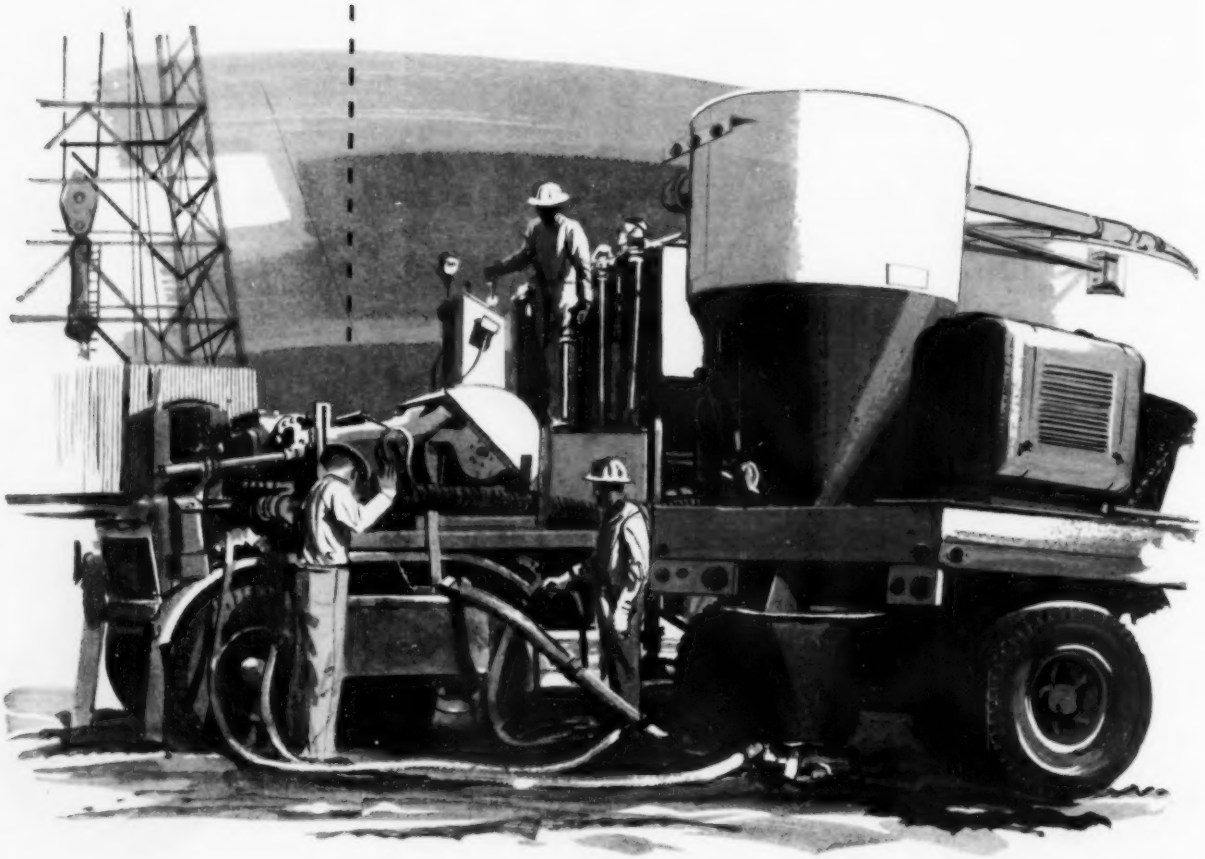
HOW HALLIBURTON HELPS YOU CUT CEMENTING COSTS

Halliburton cementing research continues to find cost reduction improvements in methods and tools for oil well cementing.

Many revolutionary improvements from Halliburton are today the standards of the industry. In addition to the more spectacular innovations, countless cost reducing developments and improvements are made through Halliburton's "perpetual engineering" program. Consider the tools shown on the opposite page . . . each has been designed for functional performance *and* to help cut cementing costs through time and equipment savings.

Add these savings to the experience of the Halliburton cementing crew, the unmatched performance of Halliburton cementing equipment, and the complete selection of Halliburton tools and materials. Time has proved this combination delivers the very *best* cementing service you can buy . . . the *only* kind Halliburton sells.



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SAVE Casing Running Rig Time

HALLIBURTON SELF-FILL DIFFERENTIAL COLLAR makes it possible to automatically fill the casing string as it is being run. With this tool in the string, frequent stops to fill the pipe *manually* are avoided. Differential pressure acting across the valve in the Self-Fill Collar automatically opens and closes the valve to maintain a nearly balanced fluid head both inside and outside the casing, even in the deepest wells. The tool may be made inoperative at any time by dropping in a weighted plastic ball, or after cement is placed, by the top cementing plug.

SAVE Surface Equipment Wear When Running Casing

HALLIBURTON CASING FLOAT COLLARS AND FLOAT SHOES are designed to take the strain of running casing off surface equipment by transferring part of the casing load to the fluid in the well as the string is being run. This "fluid-tight" seal for floating is accomplished by Halliburton's *exclusive* Super Seal Back Pressure Valve. The Super Seal Valve automatically closes after cement placement making it possible to prevent the reverse flow of cement back into the casing. Exhaustive laboratory and field tests have proved that the conical band contact design of the Halliburton Super Seal Valve and Seat exceeds the sealing effectiveness of common ball and seat arrangements in this application. Another feature built into all Halliburton Floating and Guiding Equipment is the Plug Seat. This phenolic impact plastic insert provides added stamina at the point where the cementing plug lands with the tremendous force of the pumps behind it. This extra toughness helps prevent spalling common to other casing floating and guiding tools with cement-formed seats at this most important point. All internal parts of Halliburton Floating Equipment are easily drillable, including the built-in concrete guide nose on Float Shoes and Guide Shoes. The strong, durable, rounded guide directs the casing away from ledges and obstructions to minimize side-wall caving and aids it in safely passing hard shoulders and through crooked holes as it is being run.

SAVE Tack Welding Time and Expense

HALLIBURTON WELD-A eliminates the need for tack welding the bottom casing joints. Economical, Halliburton's thread compound has proved itself to actually exceed the holding strength of tack welding at this important point in the string.

For more information on these and other Halliburton tools and services, contact your Halliburton man. He is as near as your phone.

275 Service Centers
. . . just minutes away
from your well

CEMENTING SERVICES

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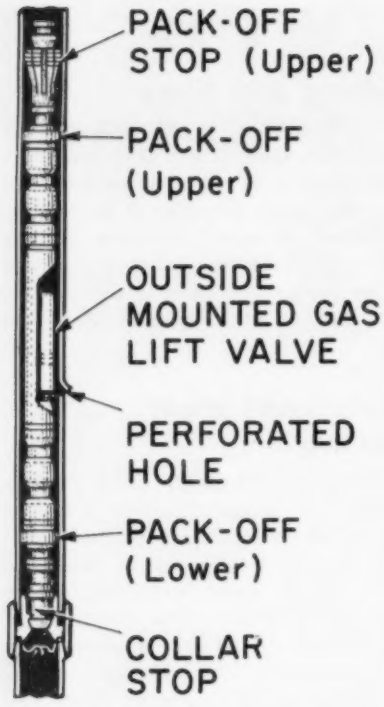

FIG. 2. Outside-mounted gas-lift valve can be used with pack-off assembly by concaving the gas-lift mandrel.

In dual completions to be gas-lifted, greater latitude is afforded by this technique in establishing compatibility for multiple strings. In other words, conventional valves can be installed on one string on initial completion and then gas lifted to determine at what pressure it will operate. Pack-off valves can then be installed in the other string set at pressures to be compatible with the conventional string.

Installation Procedure

The following installation procedure serves as a guide for installation of a typical pack-off assembly.

1. Once the location of the pack-off assemblies has been determined, the bottom collar stop is set in the nearest coupling to that point, setting the lowermost assembly first.

2. A tubing perforator is then run to that point and rests on the bottom stop. This allows a hole to be mechanically punched through the tubing some 15 in. above the tubing stop. Normally this hole will be a slot having dimensions of 3/16 in. by ¾ in. (with cam type perforator) or a 5/16-in. circular hole (with powder-charged type perforator).

3. If mud is in the annular space of the well, it is circulated out or gas-lifted out through the perforated hole, although in some instances mud has been produced out through the gas lift valve itself. In order to keep mud away from the producing interval, a circulating plug may be placed on the lowermost stop. The tubing then is perforated and mud circulated.

The well should be gas-lifted for as long as 24 hr through the perforation prior to installing the valve, in order to allow the normal flowing temperature to expand the mud in the annulus, thereby producing it to the surface. This will prevent mud from plugging the gas lift valve.

4. After the well has been sufficiently cleaned the entire upper assembly including lower pack-offs, gas lift valve, upper pack-off and upper tubing stop is run in and set on the lower collar stop as one unit (Fig. 1).

5. Successive assemblies are run up the hole at pre-determined spacing points.

6. The well is then unloaded and placed on gas lift in the conventional manner. Caution should be taken in unloading the well to unload it slowly, thereby minimizing damage to the valve from annular fluids.

Fluid Production Expected

Total fluid production possible through these installations has exceeded prior expectations. One well in particular utilizing four old-style ⅝-in. ID pack-off assemblies in 2-in. tubing produced at a rate of 1600 bbl per day total oil and water. There are several similar installations producing 800 to 1200 bbl per day.

Flowing Gradient Curves

Fig. 4 and 5 as well as Table 2 show actual flowing gradients with and without 3 pack-off assemblies in 2-in. tubing. These tests were for a production rate of 630 and 640 bbl per day (95% water) with and without pack-off assemblies, respectively. The input gas volumes were varied through an expanding orifice type gas lift valve in order to obtain flowing gradients for gas-liquid ratios in the range of 240 to 1450. These results are shown graphically in Fig. 4 and 5 with a detailed tabulation shown in Table 2.

It is noted that generally the pres-

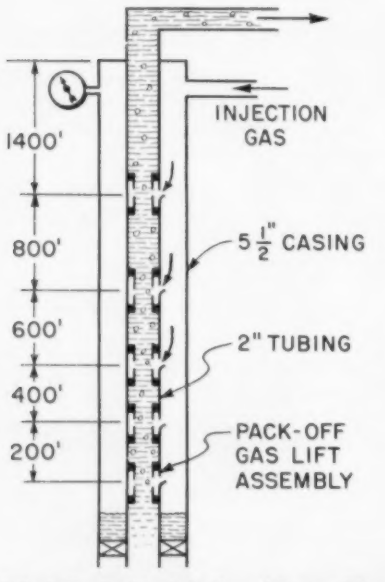

FIG. 3. Typical installation of five gas-lift valves can be made in 2-in. tubing completely by wire line.

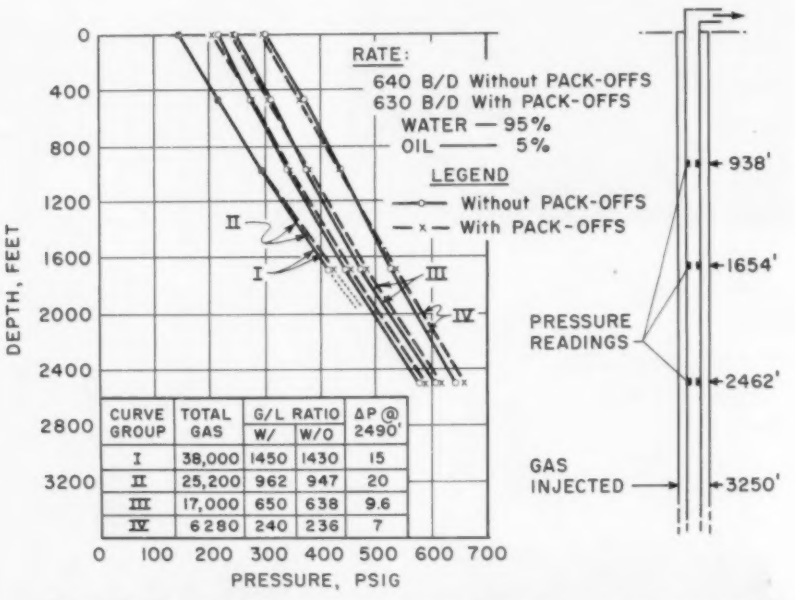

FIG. 4. Flowing gradients are compared for two installations, one producing 630 bbl of fluid per day without pack-offs, and the other producing 640 bbl per day with pack-offs.

They've both got a "business end"

In a pistol it's the muzzle . . . and in oil country tubular products it's the threaded connections. This is a vital area that helps determine performance "life-or-death." And it's here that CF&I Seamless Casing and Tubing really has what it takes for success.

Every thread is cut by modern machinery – then checked by a contour microscope that determines absolute accuracy of angle and form. No weak links survive to render hundreds of feet of pipe worthless.

In short, CF&I Casing and Tubing holds up on the job, but never holds *you* up on the job. It's available in sizes from 2⅜" to 9⅝" O. D. and meets API specification STD 5A. Ask your CF&I salesman for complete details.

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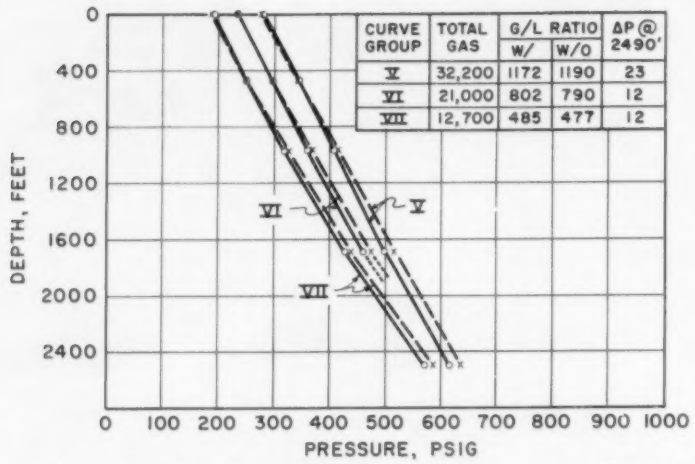

FIG. 5. Flowing gradients of actual installations are based on same conditions as illustrated in Fig. 4.

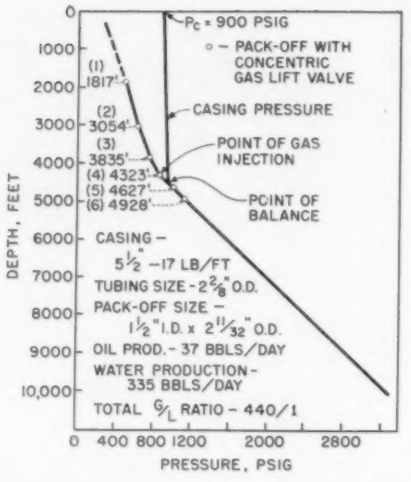

FIG. 6. Flowing pressure survey from a South Louisiana well illustrates operation of gas-lift installation using six 1½-in. ID by 2 11/32-in. OD pack-off assemblies.

sure increases to some extent as the gas-liquid ratio is increased. Curve groups VII and I offer an exception to this general trend. It is believed that some error resulted in obtaining flowing gradients for these two sets of curves. Some difficulty was experienced in maintaining the same injection gas-liquid ratio for each installation and in particular for the higher gas volumes. As noted, maximum loss in total pressure was 23 psi representing 23/3 = 7.67 psi per pack-off which could be used as a guide for ratios in the neighborhood of 1200/1, and 640 bbl per day. However, at gas-liquid ratio of less than 800/1, the maximum total loss was 12 psi, which represents only 12/3 = 4 psi per pack-off. Fig. 6 shows a typical flowing pressure survey that was run on a South Louisiana well. These were 1½-in. ID by 2 11/32-in. OD pack-off assemblies. Precaution was exercised near the top in that the well was shut in to come through the top two pack-off assemblies, and then allowed to stabilize after coming through the pack-offs.

As a matter of interest, it was noted that valve No. 5 was almost uncovered by casing gas. Casing pressure was increased and tubing pressure lowered. The well immediately increased to 600-700 bbl per day, indicating that valve No. 5 and possibly No. 6 was uncovered.

Other Applications

In addition to gas-lift installations, the pack-off assembly has been used in several other applications.

Unloads water from gas wells. This technique has been used to unload gas wells that have loaded with water. In one instance a well had to be shut in because of flood conditions. This particular gas well could not be swabbed back in because of excessive water volumes to be moved. One assembly was installed and another source of injection gas was used to unload water for 3 days, after which the well made some 3,000,000 cu ft of gas per day without gas-lift. Pulling the well to install gas lift valves would have been very expensive and mudding up the formation was considered detrimental.

Pack-off faulty gas lift valves. In many instances a pack-off assembly has been used to completely isolate a gas-lift valve that is leaking. The valve can be packed-off entirely by utilizing a solid piece of tubing between the upper and lower pack-off, or another gas-lift valve of the same surface operating pressure can be installed on the pack-off assembly.

Repair a tubing leak. It may be desirable to pack-off a tubing leak developed in a flowing well or gas-lift well. It may be that this leak has occurred on a dual installation, resulting in a loss of annular fluids. This may also occur in a dual installation in which one zone is being produced up the annular space and one zone is producing out the tubing, resulting in a comingling of produced fluids. The pack-off eliminates this problem.

Repair "blast pipe" on dual installations. In dual completions, the tubing string producing the lower zone may be subject to intense erosion from fluids being produced from the adjacent upper zone. Generally some provision is made to protect this pipe. This can be done by utilizing extra heavy pipe or pipe covered with an abrasive-re-

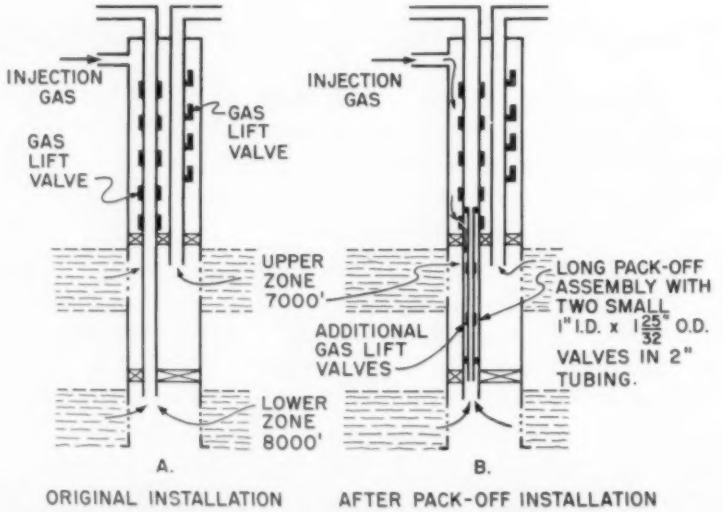

FIG. 7. Pack-off assemblies can be used to extend the depth of gas-lift valves on one zone of a dually completed well having two widely separated zones.

NEW
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Martin-Decker Electric Drilloger Recording Systems

For the recording of Total Hook Load, Pump Pressure, Pump Speed, Rotary Speed, Torque, Rate of Penetration, and R. P. M. Signals, and Pressure Signals to 20,000 pounds . . . Write for Bulletin E-P90.

MARTIN DECKER

Write for descriptive literature

MARTIN-DECKER CORPORATION

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The World's principal manufacturer of Oil Well Drilling Instrumentation

sistant material, or a combination of both. Even so, continued erosion can finally cause a hole in the pipe. The pack-off assembly gives a means of repairing this leak and extra heavy coated pipe can be used on the pack-off assembly for further protection.

Convert conventional well to single-tubing dual. In some instances it has been desirable to perforate an upper zone and place it on production without disturbing the lower zone. This has been done by perforating the zone with a tubing gun shooting through both the tubing and casing. A pack-off utilizing only pipe is then placed in the tubing, packing off the tubing holes and allowing normal production from the bottom zone. The upper zone is then produced through the tubing-casing annular space.

Extend depth of valves in conventional installation. It is possible that an incorrect reservoir analysis has resulted in valves not being placed deep enough in the original installation. Or, bottom-hole pressure may have lowered to a point such that more formation pressure drawdown is needed than is possible with the present installation. It may then be much more economical to install one or two pack-off assemblies with gas-lift valves below the present lowermost valve than to pull the tubing and risk possible formation damage.

Extend depth of valves in one zone of a dually completed well having two widely separated zones (See Fig. 7). In this instance the original depth of gas-lift valves on the weak (lower) zone was extended only to the top dual packer. Later the zone weakened to a point that the bottom hole pressure could not support fluid to the lowermost valve at a sufficient rate. A long pack-off assembly was installed as noted in Fig. 7B with two additional gas-lift valves. The lowermost valve on the original string was utilized to allow gas to pass down the annulus between the 1-in. and 2-in. tubing, and through the macaroni gas-lift valves. A noticeable increase in production resulted from the additional formation pressure drawdown.

Pack-off jet buttons. Several wells in southwest Texas have recently been equipped with pack-off gas-lift valves in order to increase production. These wells have previously been lifted by means of a jet button installed in the tubing wall by wireline tools. Production dropped due to changing well characteristics. Pack-off valves were used to straddle the jet buttons and enable the operator to lower the point of injection and to achieve one-point injection.

For chemical injection. Pack-offs may be utilized as a means of injecting corrosion inhibitors or paraffin solvents from the annular space into the tubing string.

Costs of Installation

The California Company has 56 installations at an average cost of $2576. It is estimated that $1,028,000 has been saved, comparing cost of pack-off anchor installations with workover costs. The following table shows comparative cost of pack-off anchor installations vs workover costs for various types locations in inland waters and offshore areas.

Type Well	Pack-off Anchor	Cost of Workover	Saving
Inland waters	$2000	$10,000	$ 8000
Offshore-single well str.	2500	20,000	17,500
Offshore-multiple well str.	3000	50,000	47,000

The cost of placing one complete pack-off assembly in place, including cost of all equipment, and wire-line time, is approximately $750. This unit cost would decrease if more than one assembly were placed in any one string since wireline costs per assembly would be less.

Conclusions

It is quite evident that this gas-lift technique presents a method whereby substantial savings can be realized where applicable. Direct equipment and workover costs can be reduced, but the fact that the well does not have to be killed will often more than justify applying the pack-off technique. In addition, there is a minimum of lost production due to delay in returning the well to production.

Acknowledgment

Thanks go to Goodale Oil Company for its cooperation and to The California Company for permission to publish cost analysis of 56 installations. For helpful comments and suggestions on field applications, the authors are grateful to Otis Engineering Corporation personnel. Also, appreciation is expressed to Ohio Oil Company and Sun Oil Company for permission to run the pack-off pressure gradient tests as part of an experimental gas lift project in cooperation with Otis and The University of Texas. ★ ★ ★

TABLE 1. Critical Dimensions of Pack-Off Gas-Lift Equipment.

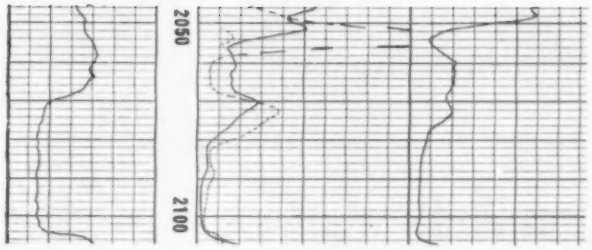
NOM. TUBING SIZE	MINIMUM I.D. of ASS'Y.	UPPER PACK OFF		GAS LIFT VALVE		LOWER PACK OFF		COLLAR STOP	
		I.D.	O.D.	I.D.	O.D.	I.D.	O.D.	I.D.	O.D.
1 1/2	3/4	3/4	1 15/32	3/4	1 13/32	3/4	1 15/32	3/4	1 15/32
2	1	1 1/16	1 27/32	1	1 25/32	1 1/16	1 27/32	1 1/16	1 27/32
2 FL. JT.	1	1 1/16	1 27/32	1	1 25/32	1 1/16	1 25/32	1 1/16	1 27/32
2 1/2	1.3	1 1/2	2 9/32	1.3	2 5/32	1 1/2	2 9/32	1 1/2	2 9/32
2 1/2	1 1/2	1 1/2	2 9/32	1 1/2	2 11/32	1 1/2	2 9/32	1 1/2	2 9/32
3	1 21/32	2	2 27/32	1 21/32	2 5/8	2	2 27/32	2	2 27/32

TABLE 2. Detailed Comparison With and Without 3 Pack-Off Assemblies.

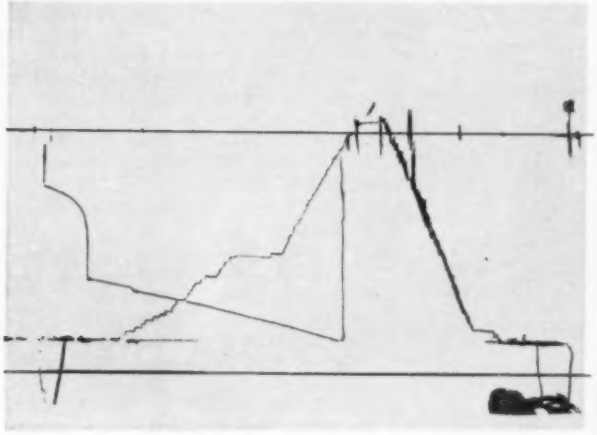
CURVE GROUP	TOTAL GAS Ft³/Hr	G/L RATIO		PRESSURE DIFFERENCE BETWEEN PACK-OFF INSTALLATION AND OPEN TUBING				
		W/ Ft³/Bbl	W/O Ft³/Bbl	TOP	477'	969'	1685'	2493'
I	38,000	1450	1430	-5	-9	-.6	+7.6	+15
V	32,200	1172	1190	-3	-1.8	+6.7	+15.3	+23
II	25,200	962	947	-5	-3.7	+4.9	+11.3	+20
VI	21,000	802	790	0	-.6	+6.2	+11.5	+12
III	17,000	650	638	0	+2.5	+2.5	+9	+9.6
VII	12,700	485	477	0	0	+4.4	+9.8	+12
IV	6280	240	236	0	-.6	+3.2	+9.2	+7

WHICH WELL WAS THE PRODUCER?
#2

WELL "C"

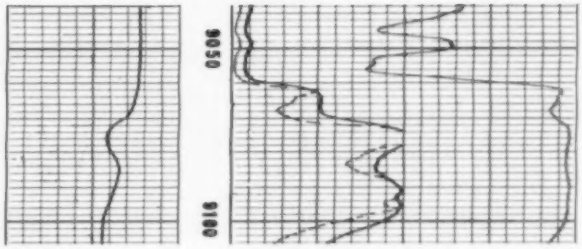


This rank wildcat was drilled to 6122'. Log analysis showed one interesting zone at interval 2068'-2080', and core analysis revealed 20% porosity with 70.5% fluid saturation (14.5% oil, 56.0% water). Both core analysis and logs indicated a transition at 2081'. Would you set casing on this well? Before reading further, study log and core information on well "D".

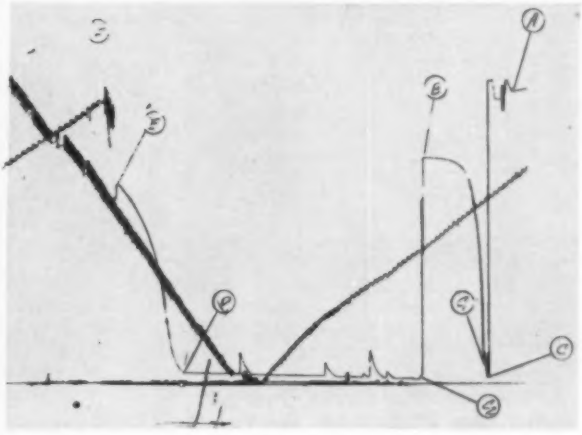


It was determined that much more conclusive data was needed before making a firm decision regarding completion of this well. Johnston Testers performed a selective zone test recovering 120' mud-cut oil, 1050' free oil and 40' salt water.

WELL "D"



Electric logs on this step-out well revealed the expected zone at interval 9066'-9092'. Log curves showed favorably. Analysis of cuttings showed an average porosity of 12% and 42% fluid saturation. Would you set casing on this well? Now study the drill stem test data on both Well "C" and Well "D" for the real answer.



Information obtained to this point showed favorably for a producer. However, a decision was made to get additional data prior to setting casing. Johnston Testers performed a 3-hour drill stem test recovering 300' of water and mud-cut water.

Well "C" became the producer flowing 90 barrels of pipeline oil daily. Well "D" is proof of the value of a Johnston drill stem test prior to setting casing. A decision based on logs and geological data alone could have been very costly. The operator of Well "D" stated that he was prepared to set 7" casing, perforate and treat the zone, and further, that the D.S.T. saved him approximately $15,000 to $20,000 . You can save thousands of dollars, too! Call Johnston Testers on your next well.

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OTIS PRODUCTION NEWS

Volume I, Number 5 **Otis Engineering Corporation • Dallas** *Production Equipment and Services*

Type WA Otis Production Packer Solves Problem in Gas Injection Well

High Pressure, Strain, Tubing Vibration Cause Initial Completion Packer's Body to Part

MIDLAND — Type WA Otis Production Packers have proved to be the solution to a serious problem encountered by a West Texas operator on a secondary recovery project. The problem was to find a packer that would stand the stress and vibration of the tubing in a number of high-pressure gas-injection wells.

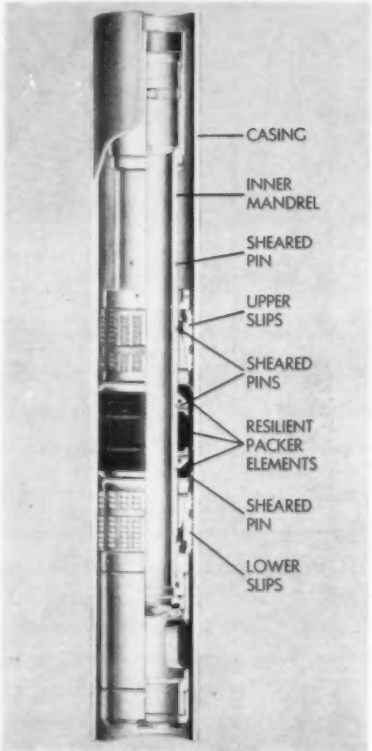
The wells involved were being used to inject gas into the Devonian at approximately 12,500 feet. Injection rate was 2½ M.C.F.D. at 7,500 P.S.I. Due to vibration created by this high rate of injection, the tubing was set in tension with a minimum of 25,000 pounds' strain. These conditions apparently proved too strenuous for the packers used in the initial completion for they disintegrated shortly after the wells were put into operation.

In analyzing this producer's problem, Otis packer specialists from the Odessa office felt confident the Type WA Otis Production Packer would stay in the hole in spite of the adverse working conditions because of the packer's "floating mandrel" design *(See diagram)*. This feature, unique among permanent-type retainer packers, is designed to prevent problems such as this which result when a packer's inner mandrel is permanently attached to the slips or packer body.

The Type WA Otis Production Packer is designed to meet today's requirements for an improved retainer packer for wire line setting. It is designed to be run into a well on an electric line and set by means of any pressure setting tool or on a hydraulic setting tool, which can be run on a sand line or electric wire line.

Unlike the packers originally used in these West Texas gas-injection wells, the inner mandrel of the Type WA Otis Packer is not pinned to either the upper or lower slips or the rubber element assembly once the packer has been set. The mandrel is free to travel up or down within the outer packer body approximately 8 inches before being confined by a shoulder at either end, and is sealed off and held in position by O-rings and pressure from the compressed rubber packer elements. In this way, vibration or movement of the tubing string when transmitted to the packer mandrel is partially absorbed by the rubber elements first, and not directly transmitted to the slips or the outer packer body.

As a result, Type WA Otis Production Packers have replaced the packers originally used in these injection wells and the operator reports all have proved satisfactory. Several additional wells are to be drilled for this project and Type WA Packers have been specified for each.



In the Type WA Otis Packer, all pins which serve to hold the slips and resilient packer elements in the running position are sheared when set, leaving the mandrel free to float.

The Type WA Otis Production Packer offers several other outstanding features in addition to its "floating mandrel" design. The packer is made of drillable materials and so designed as to minimize the time required to mill or burn over, should it become necessary to remove the packer from the well. The O.D. of the rubber elements is less than the O.D. of the end shoes to help guard against premature setting or damage to the rubber seal elements when running in. The Type WA Packer has a large bore to allow standard tubing to be used as tail pipe and to pass tubing-type perforating guns and other standard wire line tools. The back pressure valve at the bottom of the packer serves to eliminate contamination of the formation by mud or water when tubing is removed from the packer in the event BHP exceeds the hydrastatic head.

The solution to this West Texas operator's problem by an Otis Specialist was the direct result of the specialist's knowledge of his product and experience in the field. This type of help is typical of the service available from all Otis personnel. Their knowledge of production problems and of the application, installation and capacity of their equipment permits them to make sound, on-the-spot recommendations. The next time you find it necessary to consult with someone regarding packers or well completion techniques, call the Otis office nearest you or write Otis, Dept. 4-P, P.O. Box 35206, Dallas 35, Texas. You'll find experienced Otis Well Completion Specialists ready to help you . . . anxious to serve you . . . and with the widest variety of field proven production equipment available today.

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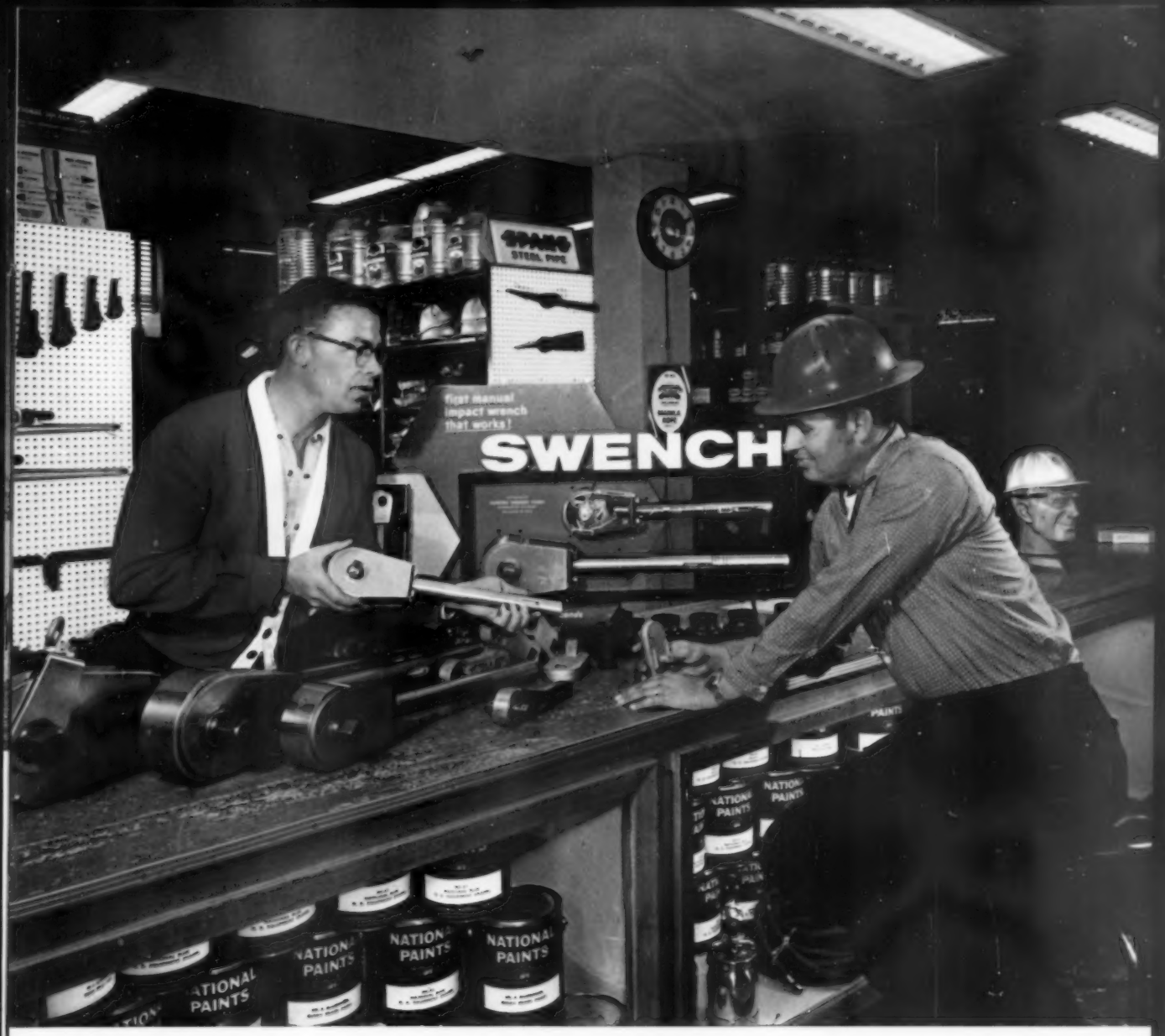


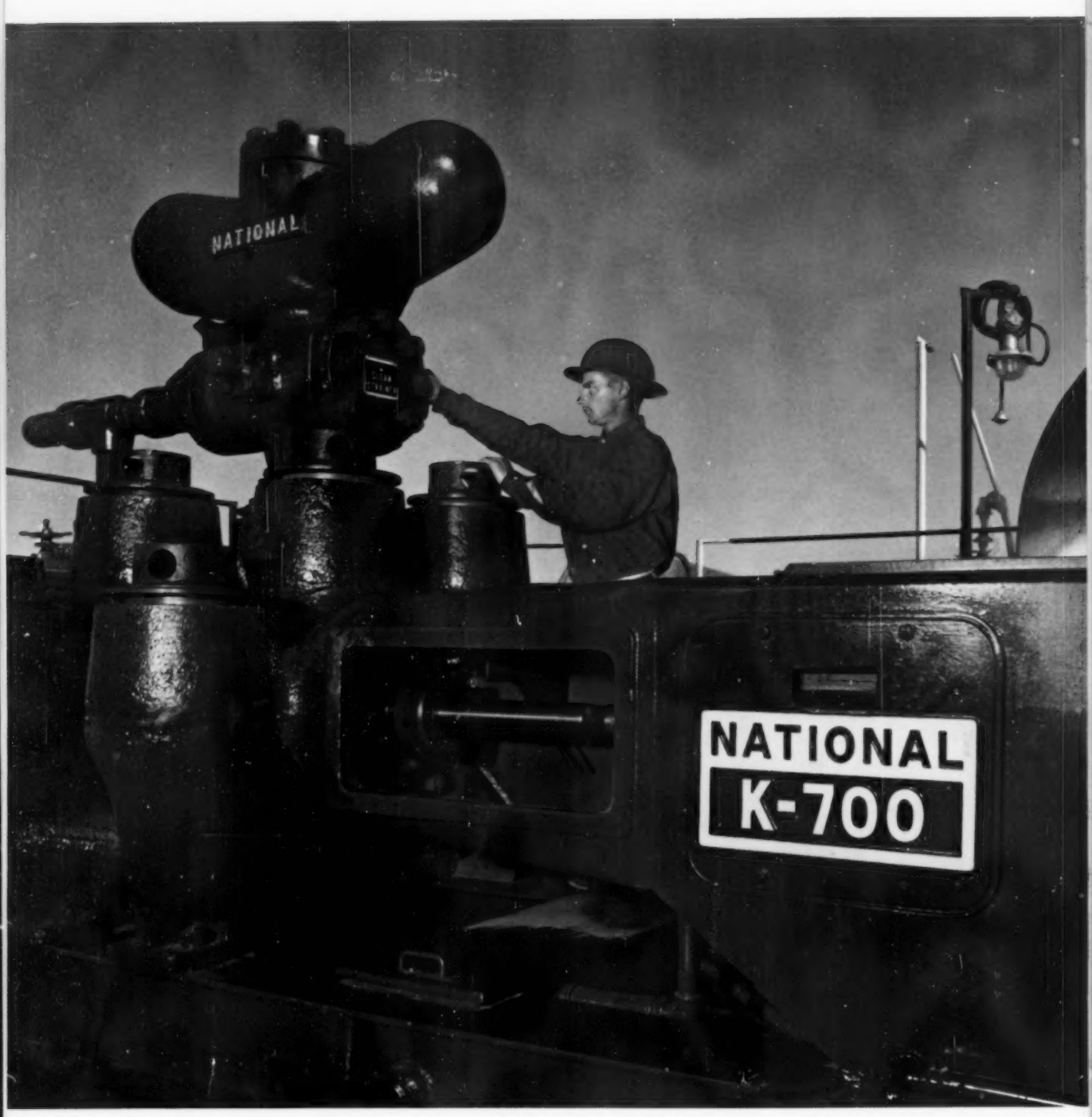
Now! Time-saving Swench Wrenches are available through National Supply Stores

Unique Swench Wrenches are now distributed through National Supply stores. Swenches are a new concept in manual impact wrench design. Many oil field users have enjoyed considerable savings with these wrenches. They not only reduce costly man hours, but they save valuable equipment from damage resulting from heavy sledging of manual wrenches and cheater bars. Nuts that previously had to be burned off can now be "swenched off" by one man in a matter of minutes. Next time you visit your National Supply Store ask for a quick and convincing demonstration.

This exciting new product is typical of the thousands of products available immediately through the 120 conveniently located National Supply Stores. The products vary widely, but they all have one thing in common. Each is made by an established manufacturer with a proven reputation for quality and reliability.

On next pages: National Supply power slush pumps

How National Supply help reduce



This is a National K-700 power slush pump installed in a preliminary rig-up at Houston, Texas. There is a National pump to meet every horsepower requirement from 80 to 1,250 hp. Investigate the many new features of these pumps.

POWER SLUSH PUMPS
mud system costs

Next time you buy a power slush pump be sure to investigate the many cost saving features of National Supply pumps. You'll find new designs, fast maintenance features, high strength with light weight construction, in a complete range from 80 to 1,250 input horsepower.

Each National pump is designed to meet specific requirements of modern drilling operations. You'll find National pumps give you longer trouble-free service, under more severe conditions, than any comparable pump you can buy.

Here are five of the newest National power slush pumps that incorporate design features needed in modern jet drilling. Features vary with the pump to meet the requirements for which each particular pump is recommended.

K-380 This is a completely new 380 input horsepower slush pump with a new-design fluid end incorporating many features for smoother operation, longer life and easier maintenance. The fluid end is a high strength steel casting with large, direct, smoothly contoured suction passages that minimize resistance to fluid flow. This pump has high structural rigidity, yet is exceptionally light in relation to its 380 input horsepower. A tapered crosshead pin simplifies removal and reassembly of the crosshead, assures perfect alignment. "Fast Change" threaded valve pot cover plates make maintenance easier and encourage frequent inspection of valves and seats. This important feature is found in each of the five pumps described here. Write for Bulletin 520.

K-500 This new 513 input horsepower slush pump provides a high degree of accessibility, which simplifies and speeds up routine maintenance operations. Despite its light weight and compactness, the K-500 is built with typical National durability. The threaded cylinder head and valve pot arrangements permit rapid removal of all related fluid end parts, including the liner, without removing the fluid cylinder head body. Write for Bulletin 500.

K-700 This new National power slush pump is exceptionally light in weight for the 700 input horsepower rating. "Fast Change" threaded valve pot cover plates and cylinder heads are important features. Fluid end is a one-piece steel casting with streamlined internal passages. Cylindrical sections give maximum strength. The fluid end on all National slush pumps is given a thorough hydrostatic test before final assembly. Main frame is fabricated of shaped and formed steel plates, structurals and steel castings, electrically welded into a unit with high structural rigidity. Write for Bulletin 501.

H-850-A National's engineers used a new approach in designing the power end frame for the H-850-A power slush pump. It is a streamlined, super strengthened box-type unit with structural rigidity and durability sufficient to withstand the severest service. Design reduces stresses produced by stroke reversals to the point where they are negligible. Design also incorporates "Fast Change" threaded valve pot cover plates and cylinder heads for fast maintenance. The H-850-A, rated at 850 input horsepower, is built for long pump life with minimum maintenance. Write for Bulletin 497 and supplement.

H-1250 Unique design features of the H-1250 result in reduced cylinder bore wear, longer liner packing service, longer life for connecting rod and main bearings, fast and efficient lubrication. Threaded valve pot cover plates speed inspection of valves and seats. The H-1250 is portable, due to its light weight in relation to its 1250 input horsepower. Get complete details of the H-1250 by writing for Bulletin 502.

All of these pumps, except the K-380, are available with the National Pulsation Dampener. Rig air supply operates the dampener without need for high pressure air supply or any nitrogen supply for pre-charging.

A National Supply representative will be happy to recommend the exact power slush pump to meet your requirements. He will point out the cost-saving features of each of these new pumps. Write to National Supply Division, Armco Steel Corporation, Two Gateway Center, Pittsburgh 22, Pennsylvania.

Steel

Steel's Symbol of strength, long life, and economy

National fluid end parts are carefully packaged and shipped to assure delivery in factory-perfect condition.

New performance records prove National Super Dual Seal pistons reduce pumping costs . . . add liner life

Performance records prove conclusively that operators can run pumps cheaper with National Super Dual Seal pistons. And, in addition to piston savings, longer liner life can be expected.

Here are some reasons why Super Dual Seal pistons are superior: Exclusive Dual Seal lips provide more effective seal than single lip construction, reduce fluid bypass that results in softening of fabric backing, principal cause of piston failure.

Separate inner and outer cups allow greater flexibility in material selection. Each cup is moulded of rubber compound best suited for its specific function. Pistons are available in both regular and oil resisting compounds.

A void between the two cups serves as a lubricant reservoir that is especially valuable during the priming period. Angle of plate and rubbers is designed to provide adequate room for rubber when piston is installed in the liner.

Forged steel hub will not expand under heavy pressure. Hub is designed to provide interchangeable cup assemblies in A.P.I. 3, 4, 5 or 6 tapers, sizes 6″ through 7¾″.

As a leading pump manufacturer, National Supply has the experience and facilities to produce fluid end parts to meet the most exacting quality standards. In addition to the Super Dual Seal pistons, the following National parts are readily available when and where you need them:

FLUID PISTON ROD PACKING—Fluid pressure actuates the sealing lips. The greater the pressure, the tighter the seal, yet the solid make-up through the body of the packing minimizes danger of overtightening it when it is installed. Rod wear is sharply reduced, because lip pressure is never excessive.

FLUID CYLINDER LINERS—Here are three strong reasons why it pays to use new National Liners. The specified finish and size on the OD assures proper fit with the pump bore. The bore is machined true and concentric with the OD, assuring proper alignment and maximum service life of related parts—piston, rod and rod packing. You get a properly sized and hardened bore in a correctly heat treated forging of known quality to back up the hardened bore.

FLUID CYLINDER LINER PACKING—Resistant to oil, gas heat and chemicals, National Liner Sleeves provide a perfect seal between the liner and pump bore. They are sufficiently hard to be confined in the packing space, preventing excessive flowing and pinching, yet they retain ample resiliency for proper sealing action.

"BLUE STRIPE" AND "BLUE CHROME" PISTON RODS WITH API TAPERS have maximum tensile strength and high resistance to impact. Precision ground and polished to reduce wear of both packing and rod. "Blue Chrome" Piston Rods have a super-hard, abrasion-resistant chrome finish which gives added packing and rod life.

TYPE G-2 FLUID VALVES AND SEATS promote maximum pump efficiency, with maximum effective opening for fluid flow to permit complete filling at high speed. The lower guide, integral with the valve, has a large contact area which reduces wear and minimizes possibility of cocking. A heavy clamp plate and lock gives longer valve service life.

Specify National Fluid End Parts next time you buy. Ask your representative, or write direct to National Supply Division, Armco Steel Corporation, Two Gateway Center, Pittsburgh 22, Pa.

ARMCO National Supply Division

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Because they're the simplest, D+B Two-Zone Pumps are the easiest to install, operate, adjust or repair. Result? Added economy and volumetric efficiency.

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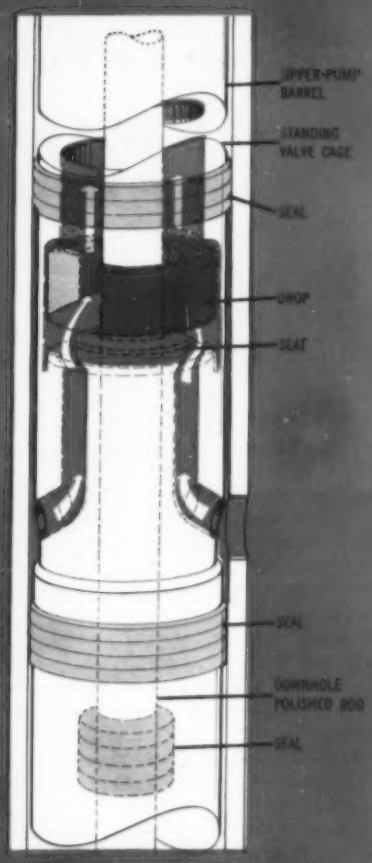
Continental's 78 strategically-located D+B Pump Shops slash your downtime with fast, efficient service . . anywhere. There's always a skilled D+B Specialist nearby to recommend pumps, supervise installation, analyze your problems and oversee repairs.

Get the full story on D+B Pumps for multizone applications. Ask your Continental-Emsco man, or write for Bulletin No. A-355.



EXCLUSIVE

Patented D+B Standing Valve Provides Matchless Flexibility and Volumetric Efficiency

This exclusive upper-pump standing valve eliminates hydraulic inefficiencies associated with "traveling standing valves." It offers the efficiency of a standard pump, plus all the flexibility required for multizone completions. Attached immediately below the upper pump barrel, it provides the closest possible spacing of standing and traveling valves for maximum compression. Its generous opening reduces gas "break out."

The simplified upper pump has only three special components: standing valve, pack-off and hold-down. Their extreme short length minimizes eccentric alignment of seals, reduces friction and eases installation in crooked holes.

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Theoretical Studies Evaluate . . .

DYNAMIC STRESSES IN LONG DRILL PIPE STRINGS

. . . Due to Setting Slips While Pipe Is Moving

THAD VREELAND, JR.,
California Institute of Technology, Pasadena, California, and Consultant for Abegg & Reinhold Company

A 15,000-FT STRING of Grade E drill pipe is capable of stretching 37 ft without yielding. If the pipe were infinitely rigid so it would not stretch, it would break at the slips as soon as they were set. Fortunately, the pipe is not rigid, but is capable of stretching without permanent elongation provided the stress developed does not exceed the yield point of the pipe material. This ability to stretch allows the top of the pipe to be stopped suddenly while the bottom of the pipe continues to move.

Whenever slips are set on moving drill pipe, dynamic stresses are added to the stresses already in the string. Parting or permanent elongation could result from these stresses depending upon the string length and upon the velocity of the pipe when the slips are set. An investigation into these stresses shows what are the critical slip setting velocities and how much effect slowing down the pipe velocity can have on the magnitude of these stresses. This study also reveals that the expense and inconvenience of shock-absorbing devices can hardly be justified for protection of drill pipe since only relatively small shock reduction is practical.

How Stresses Are Propagated

Larger stresses are produced by stopping the pipe suddenly rather than by slowly stopping it as will be shown. We will first consider the case in which the section gripped by the slips is stopped instantaneously. Time, t, will be measured from the instant the slips are set, and we will measure distance, x, down the pipe string from the bottom of the slips, as shown in Fig. 1.

When forces are *suddenly* applied to elastic members, stress waves are produced, analogous to waves produced on the surface of a pond by a dropping pebble. These waves propagate away from the source of the disturbance. It may be shown that stress waves in long slender members, such as the stress wave resulting from suddenly clamping the moving pipe in the slips, travel at the characteristic velocity:

$$c_o = \sqrt{\frac{E}{\rho}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Where,

c_o = characteristic wave velocity
E = modulus of elasticity of the material
ρ = mass per unit volume of the material[1]

The stress associated with a sudden change in velocity may be found by considering the momentum change of an element of pipe, Δx as the stress wave traveling at velocity c_o passes along the element. Let the tensile stress existing at the element be σ (this stress is due to the weight of the pipe string below the element), and let the stress increment due to changing the velocity of the pipe be $\Delta\sigma$. While the stress wave $\Delta\sigma$ is traversing the element, the stresses on the ends of the element are as shown in Fig. 2a.

These stresses give rise to a net force on the element equal to $\Delta\sigma A$, where A = cross sectional area of the pipe. This force acts for the time $\Delta x/c_o$ (the time required for the stress wave to traverse the element). This stress imparts an upward impulse $(\Delta\sigma A)(\Delta x/c_o)$ to the element which must be equal to the change in momentum $(\rho A \Delta x)\,\Delta v$, where Δv is the change in velocity of the element (Δv is taken positive for a decrease in pipe velocity). Therefore:

$$\Delta\sigma = \rho c_o \Delta v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The quantity $\rho c_o = \sqrt{\rho E}$ is approximately equal to 150 lb sec per in.^{3} for steel, so if velocity is expressed in inches per second,

$$\Delta\sigma = 150\,\Delta v \text{ psi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2a)$$

In the case of the suddenly stopped pipe, the change in velocity is equal to the initial velocity, V, and the increment of load due to stopping the pipe is:

$$\Delta\sigma A = \rho c_o V A \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

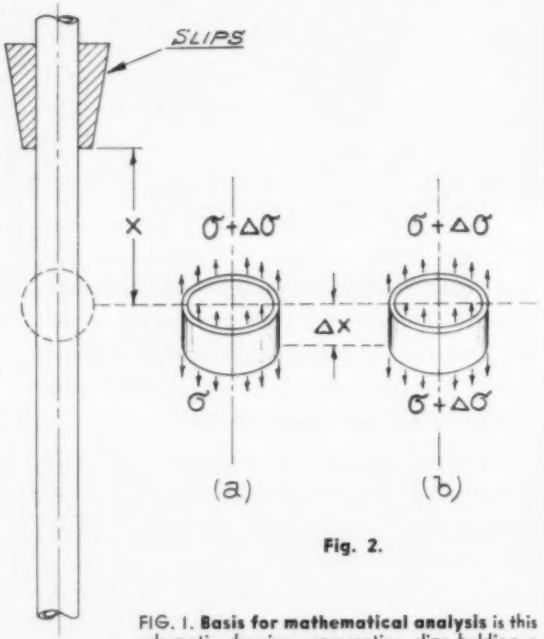

Fig. 2.

FIG. 1. **Basis for mathematical analysis** is this schematic drawing representing slips holding a string of drill pipe.

Fig. 1.

FIG. 2. **Cross section of drill pipe illustrating stresses.** 2(a) Stresses on the ends of the pipe element when a stress wave $\Delta\sigma$ reaches the element. 2(b) Stresses when the stress wave passes the pipe element.

the start of long liner life

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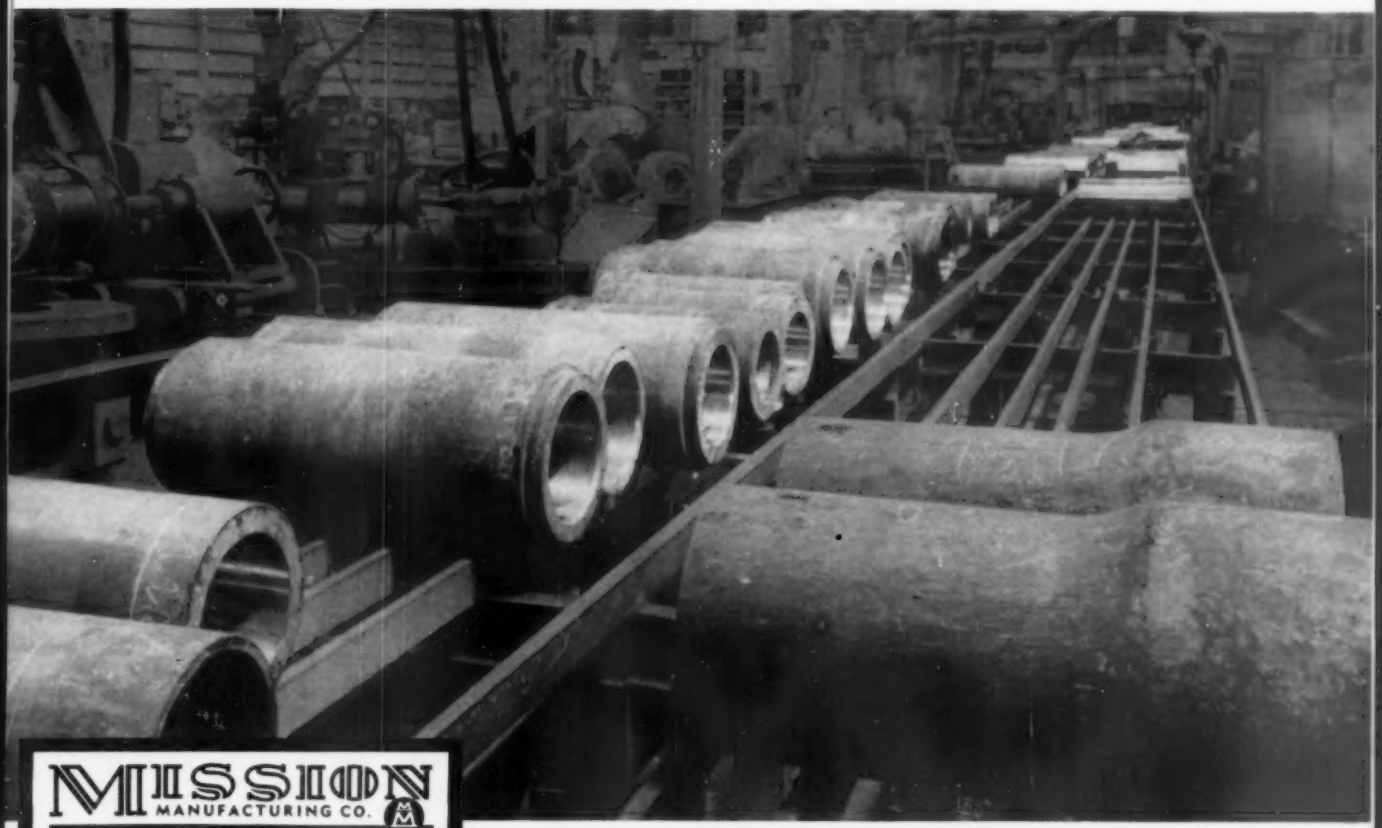

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Return Stress Waves

When the stress wave reaches the bottom of the string, the entire string is subjected to the additional increment of stress $\Delta\sigma$ and has zero velocity. If the bottom of the pipe is free of stress, an unloading wave will travel up the pipe at velocity c_o. The velocity of the pipe below the unloading wave front is upward and equal to the initial velocity V. The unloading stress wave reaches the slips at $t = 2L/c_o$ where L is the length of the pipe string. The slips are subjected to an upward force $\rho c_o VA$ at that time.

There is a distinct possibility that this force could throw the slips out of the master bushing, releasing the pipe. The probability of this occurring is considerably increased when gripping dies, slip bodies, and master bushings are in a worn condition as they then present only a minimum of contact and friction holding.

If the slips do not suddenly stop the pipe, but stop it before the unloading stress returns to the slips, Equation 3 applies and gives the maximum increment of load due to stopping the pipe. If the pipe is not completely stopped, the maximum increment of load is less than that given by Equation 3 because the unloading stress reduces the total stress in the pipe. Yielding of the pipe takes place in the slip area when the force in the pipe reaches a critical value. If F_m is this critical force, yielding will start when:

$$F_m = W + \rho c_o VA$$

where W is the weight of pipe below the slips. The maximum weight that can be stopped without plastic deformation is:

$$W = F_m - \rho c_o VA \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The critical velocity to start yielding is

$$V_e = \frac{F_m - W}{\rho c_o A} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Affect of Tool Joints

An actual pipe string has joints which are of different cross-sectional area than the pipe itself. Such changes in area cause a stress wave to be modified, part of the stress wave being reflected, and part propagating through the joint. Such stress wave reflections are unimportant in pipe strings if the time required for the slips to stop the top of the pipe is much longer than the time for the stress wave to travel through the joint.

For a 2-ft joint length, the travel time in steel is:

$$\frac{2 \text{ ft}}{17{,}000 \text{ ft/sec}} = 120 \times 10^{-6} \text{ sec.}$$

This time is considerably shorter than the time required for the slips to completely stop the gripped section of the pipe, so stress wave reflections at pipe joints are unimportant.

ABOUT THE AUTHOR

Thad Vreeland, Jr., is associate professor of mechanical engineering at the California Institute of Technology at Pasadena. He holds BS, MS, and PhD degrees from Cal Tech, obtaining his doctorate in 1952, from which time he has taught subjects ranging from stress analysis to metallurgy. His industry experience consists of consulting work in metals, stress analysis, and mechanics.

Load on Slips

When the slips are set, the total load $W + \rho c_o VA$ is applied to the slips and master bushing. The weight of the pipe string which was carried by the hook is transferred to the table along with the increment due to the change in pipe velocity, $\rho c_o VA$.

As an example, consider stopping a string of 4½-in., 16.6-lb per ft, Grade E pipe. A force of 262,000 lb will start yielding in the slip area with a transverse load factor of 3,[2] so $F_m = 262{,}000$ lb. If the pipe string was horizontal so that W = O, the critical velocity would be:

$$\begin{aligned} V_e &= (262{,}000 \text{ lb})/(150 \text{ lb sec/in.}^3)\ (4.41 \text{ in.}^2) \\ &= 396 \text{ in./sec} = 33 \text{ ft/sec} \\ &= 22.5 \text{ mph.} \end{aligned}$$

The critical velocity to start yielding is then 33 ft per sec when there is no initial load on the pipe.

Slips are normally set when the pipe velocity is 3 ft per sec or less. The increment of load which is produced by suddenly stopping the pipe initially traveling at 3 ft per sec is:

$$\begin{aligned} \rho c_o VA &= (150 \text{ lb sec/in.}^3)\ (36 \text{ in./sec.})\ (4.41 \text{ in.}^2) \\ &= 23{,}800 \text{ lb.} \end{aligned}$$

The weight of pipe below the slips which will just start yielding in the slip area when the pipe is stopped from a velocity of 3 ft per sec is then $W = F_m - \rho c_o AV = 262{,}000 - 23{,}800 = 238{,}200$ lb. The dynamic stresses due to setting the slips when the pipe is traveling at 3 ft per sec lowers the allowable weight of the string by 9%. A pipe velocity of 1 ft per sec lowers the allowable weight of the string by 3%.

Reducing Dynamic Stresses

The dynamic stresses due to setting the slips on moving pipe may be lowered by (a) reducing the pipe velocity before the slips are set, or (b) allowing the slips and master bushing to move so that the pipe does not come to rest before the unloading reflection returns from the bottom of the string (Δv is less than V in the time interval $2L/c_o$ after the slips are set).

If a 50% reduction in shock is achieved by cushioning when the pipe is traveling at 3 ft per sec, the allowable weight of the string is increased by 4.5% or 11,900 lb. If the pipe is traveling at 1 ft per sec, a 50% reduction in shock would increase the allowable weight of the string by only 3930 lb. *For such relatively small reductions in dynamic stresses the expense and inconvenience of shock absorbing devices can hardly be justified.*

There is another reason why it is impractical to achieve a significant reduction in the dynamic stresses encountered in long strings by cushioning the master bushing or rotary table. Large displacements are required in order to bring the pipe to rest in a time greater than $2L/c_o$ when the string is long. As an example, for a 50% reduction in dynamic stresses in a 17,000 ft string with V = 3 ft per sec, Δv must be less than V/2 in the time $2L/c_o$, or less than 1.5 ft per sec in 2 sec. The average velocity during the 2 sec would be 2.25 ft per sec with constant deceleration and the displacement would be 4.5 ft. Additional displacement would be required to stop the pipe. Since such large displacements are impractical, it is more practical to reduce dynamic stresses by reducing pipe velocity prior to setting the slips.

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1. S. Timoshenko, "Theory of Elasticity," McGraw-Hill, 1st edition, p. 382.

2. W. H. Spiri and W. B. Reinhold, "Why Does Drill Pipe Fail in the Slip Area," *World Oil*, Oct. 1959.

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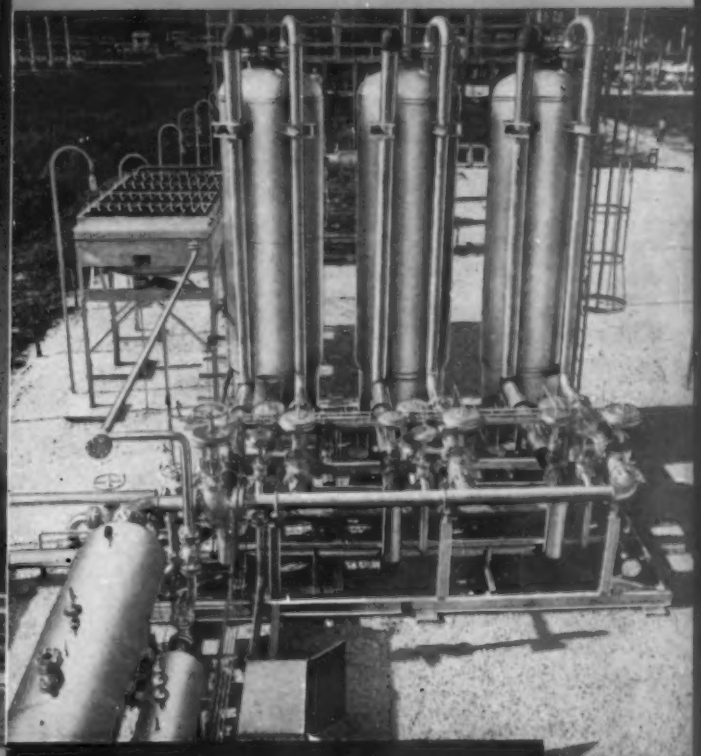
Rich Stream -- Lean Stream



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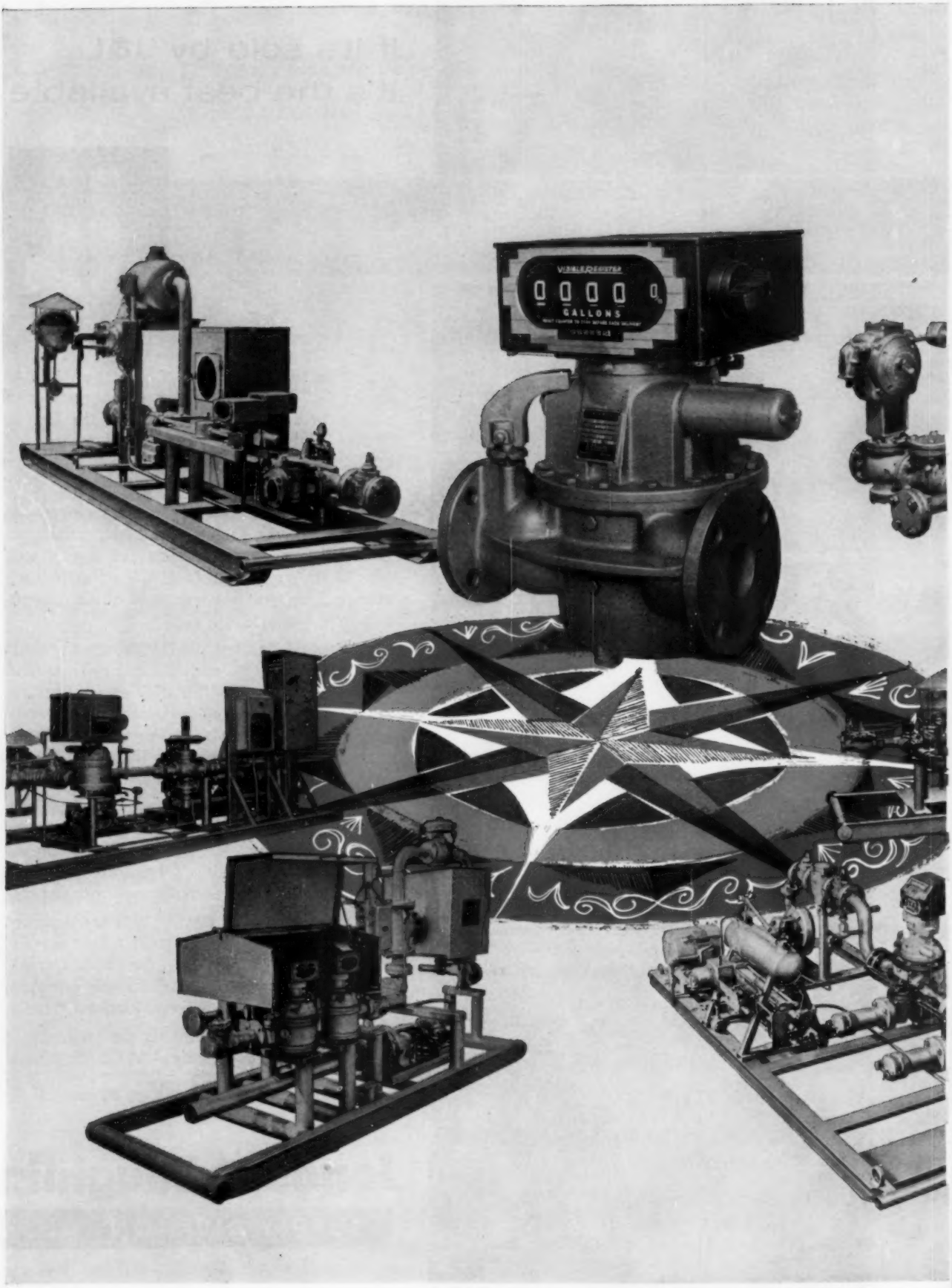
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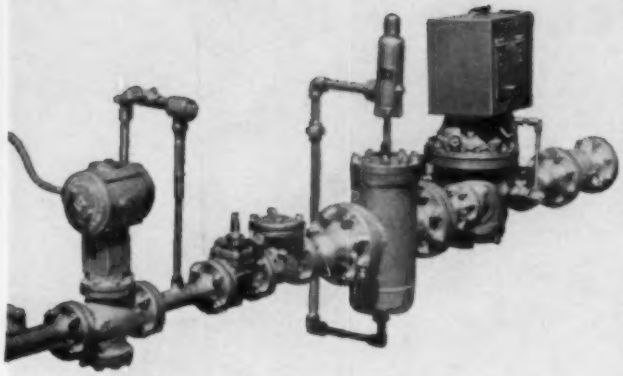

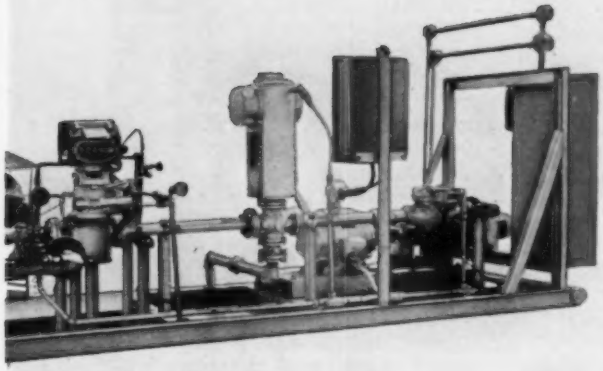

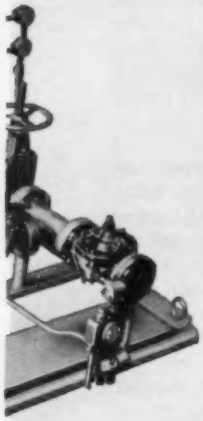

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STOP POUNDING THAT PUMPING WELL

J. S. MARTIN, *Continental-Emsco Company, Dallas, Texas*

If you try to pump more liquid from a well than flows into the bore, you usually will cause it to pound. Liquid pounding sets up high peak stresses in all equipment and can result in early failures and costly repairs

POUNDING A PUMPING WELL down can cause premature failure of the prime mover, unit pumper's gear reducer, sucker rod string and the pump itself. Particularly is the gear reducer adversely affected. The cost to replace or repair the gear reducer can amount to half the price of a new unit pumper. In this light, it behooves the producer to minimize pounding and reduce the chance of subsequent gear reducer failures.

The practice of "pounding a well down" is quite prevalent in many fields . . . and especially so in stripper production. It is also encountered frequently in waterflood operations where producing wells are pumped. The term "pounding" is appropriate enough, for it describes what happens when a long string of rods with a pump plunger on bottom suddenly strike a liquid. The impact is transmitted up the rods, through the unit pumper and gear reducer and back to the prime mover.

Three distinct types of well pounding initiated at the bottom-hole pump (other than pounding caused by a misspaced pump) are: (1) gas pounding; (2) vapor pounding; and (3) liquid pounding. Liquid pounding is the most destructive and this discussion will be limited to this type of pounding.

Destructive forces produced by pounding are felt from the bottom-hole pump (where the pound originates) to the prime mover. What is the nature of these detrimental forces on the prime mover, rods and pump? What happens in the gear reducer in the way of peak stresses?

Torque Variations in Prime Mover

Torque loading upon the prime mover is proportional to the torque occurring in the gear reducer. An analysis of gear reducer loads will show clearly why clutch failures occur and why shaft and bearings fail in electric motors when a well is pounded. Although the vee belts absorb some of the shock, they must transmit the rotating force (torque) from gear reducer to prime mover (and vice versa), so it is understood why any extreme variation in torque also adversely affects the prime mover.

Effects on Gear Reducer

Fig. 1 is a dynagraph taken from a well being "pounded down" in an Oklahoma field. The unit pumper involved is an API 57,000 in.-lb gear reducer unit, driven by a 10-hp single cylinder engine. Only torque loading is analyzed here.

Table 1 shows determinations of net torque at the low speed shaft, using API torque factors. Pound down traces numbered 1, 2, and 3 on the card are similarly identified in the determinations.

Fig. 2 graphically demonstrates the net torque being imposed upon the gear reducer. Note that trace 1 overloads the reducer 40%. Some of this could be corrected by counterbalance if the card continuously repeated itself as per trace 1. This is virtually never the case, however, when wells are being pounded.

In Fig. 2, the counterbalance is correct for trace 3, resulting in almost equal torque peaks up and down and within the reducer's capacity. This serves to illustrate why there is seldom a "correct" counterbalance under such circumstances, since most pounding wells cycle through more varied downstroke traces than shown on the card.

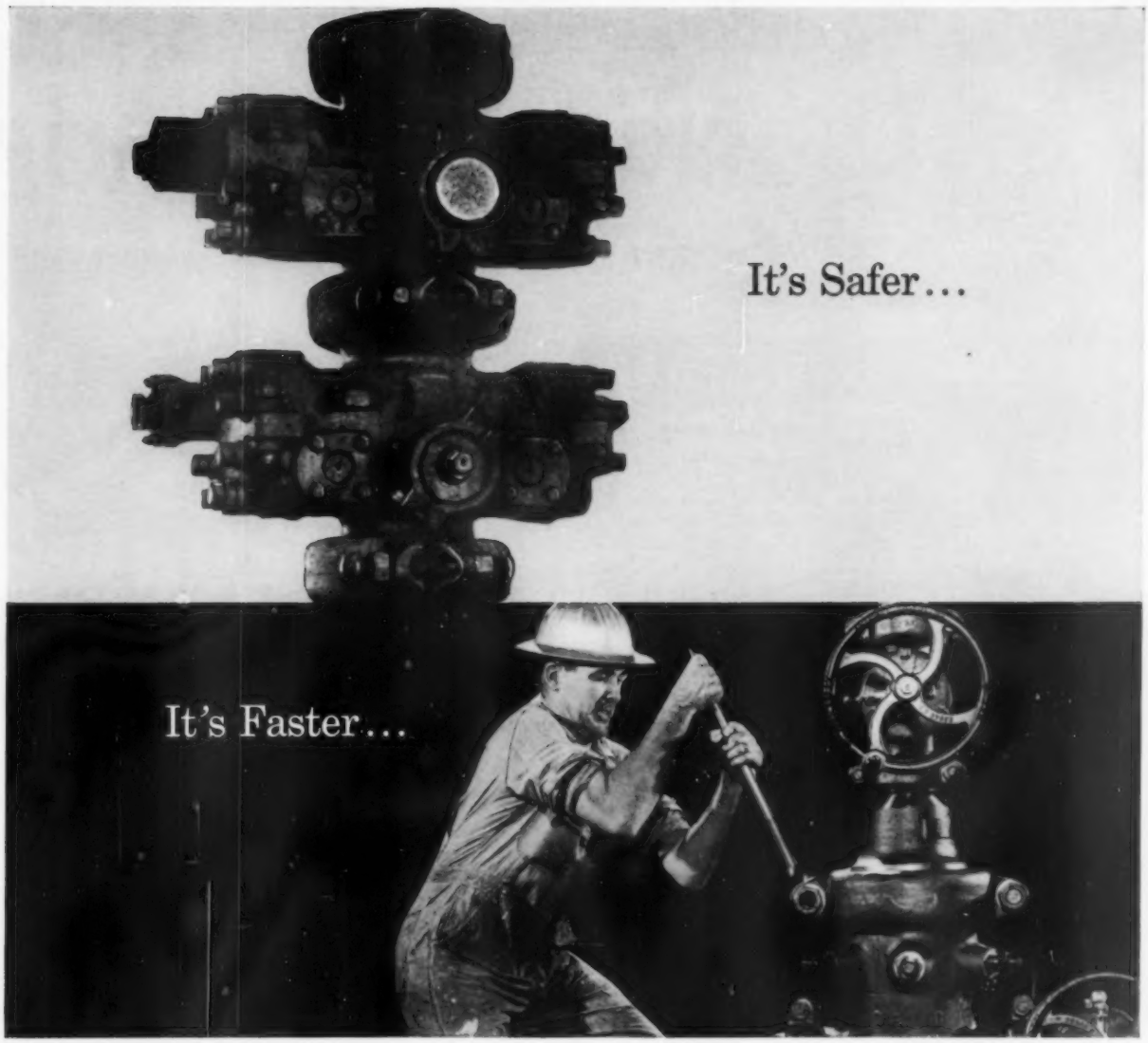
Considerable crank angle is consumed by negative torque. Negative torque will always be experienced and is to be expected in rotary counterbalanced units.

Fig. 3 shows what happens in a gear reducer acting under negative torque. Backlash (tooth clearance) is a function of the design of the gear and pinion teeth. Without proper tooth clearance, gear teeth would break off when engaged and rotated. However, the more backlash (tooth clearance) present in the two gears, the greater the "jump" will be when the pinion ceases to drive the low speed gear (positive torque as shown in left-hand drawing of Fig. 3) and begins braking the low speed gear (negative torque as shown in the right-hand drawing of Fig. 3).

A particularly destructive force, directly attributable to pounding wells, becomes apparent when one observes that the two most important criteria determining the destructiveness of the impact when going from positive to negative torque on the teeth are:

1. Distance traveled (backlash or clearance).
2. Rate of change, which determines velocity at the time of impact.

An inspection of that part of the card (traces 1, 2, and 3) involved in the pound, and caused by the pound, reveals a quite rapid rate of change,



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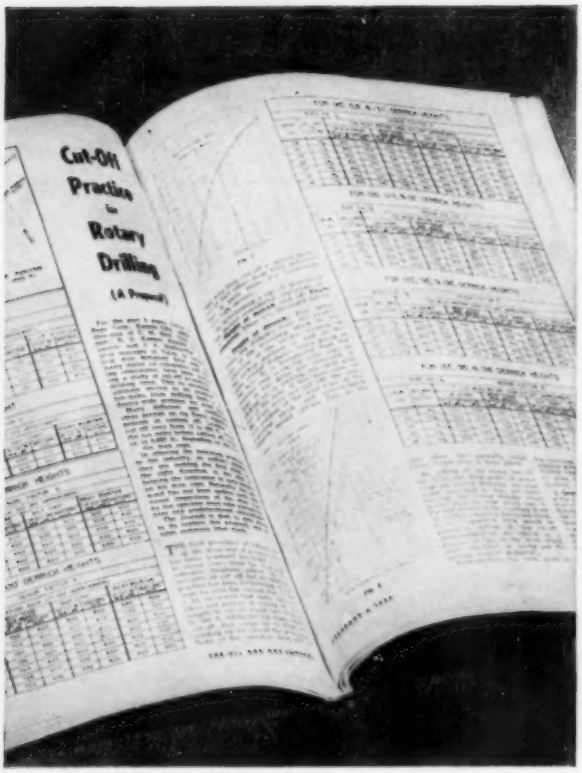

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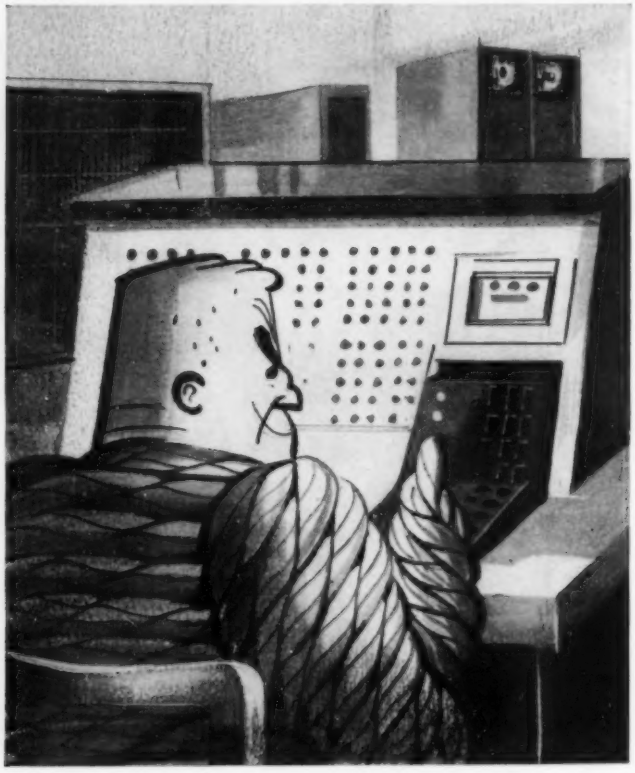

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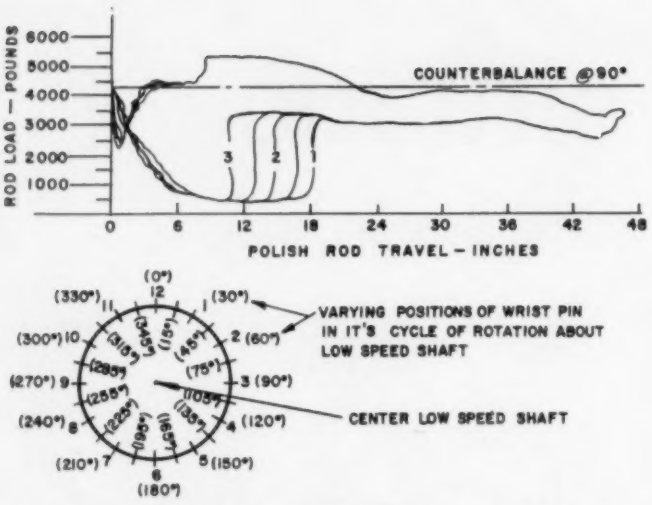

FIG. 1. **Dynagraph of a pounding well** in Oklahoma. Crank angle of wrist pin about low speed shaft when viewed towards right side of unit and "o'clock" positions are also shown. Unit pumper has a 57,000 in.-lb gear reducer unit and is driven by a 10-hp single-cylinder engine.

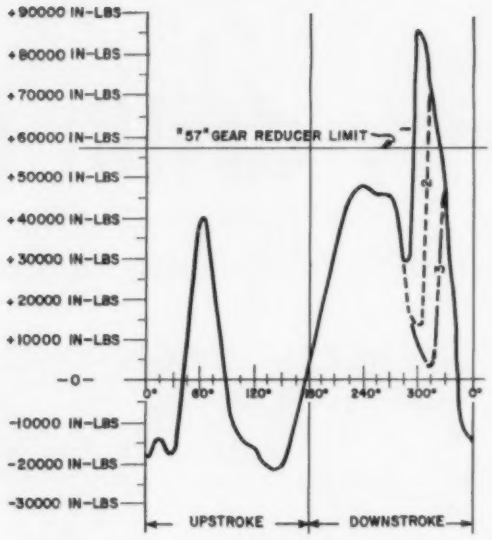

FIG. 2. **Net torque on gear reducer** computed from dynagraph of Fig. 1. Note trace 1 overloads reducer by 40%.

(see Fig. 2) especially when it is considered the well was pumped at 22 by 46 in. cycles per min.

Other Stress Considerations

Data presented in Table 1 and Fig. 2 were computed by API procedure using torque factors. Unfortunately, this procedure does not take into consideration the "flywheel" effect of the rotary counterbalance.

Many times, under "pound-down" conditions, the weights literally "run into" the well load at the critical point on the downstroke. On the downstroke, the counterbalance is contributing the positive leg of torque, the well load is contributing the negative leg of torque, and the difference between the two is net torque. The **actual** torque on the gear reducer is greatly increased (over API determinations) in actuality when the weights slow down and deliver their inertia into the gear reducer. Since the dynamometer is at the polished rod it cannot record the inertia gain of the counterweights.

The **actual** torque peaks on the downstroke, due to counterbalance inertia impact (particularly between and including traces 1 and 2), are undoubtedly as much as **50% more** in actuality than the API calculation(s) indicate. In the case of trace 1, the actual load imposed on a 57,000 in.-lb gear reducer would be 120,000 in.-lb, or 214% greater than its rated capacity.

It is easy to understand why gear reducers can and do fail under pounding conditions. Yet **theoretically**, using recognized and accepted formula (based on the fluid being produced from the depth involved), only a fractional load torque-wise on the gear reducer **should be** present. When the unit was "sized" and bought, theory indicated one size was sufficient, when in actuality under pounding conditions at least twice the capacity in the gear reducer is necessary.

Under pound down conditions, there is no one best counterbalance, but the destructive conditions previously cited would be felt to some degree irregardless of counterbalance setting.

Sucker Rod Stresses

Without going into details, since the main intent of this article was to pinpoint gear reducer loads from an actual dynagraph of a well being pounded down, we wish to point out the following can occur to the sucker rod string when a fluid pound is present:

1. Stress ranges are increased, often times to where they approach 100% based on the formula:

$$\text{Stress range in \%} = \frac{\text{PPRL} - \text{MPRL} \times (100)}{\text{PPRL}}$$

Where: PPRL = Peak Polished Rod Load

Table 1. Net Torque Determinations According to API Procedures for Well Dynagraph Shown in Fig. 1.

ANGLE (deg.)	WEIGHT (lb)	TORQUE F	GROSS TORQUE (in.-lb)	CB TORQUE @ 90° (in.-lb)	SINE ANGLE	NET CB TORQUE (in.-lb)	NET TORQUE (in.-lb)
0	3750	— 4.70	— 17,600	108,000	0	0	—17,600
15	3500	3.76	13,200	108,000	.26	— 28,100	—14,900
30	3000	12.45	37,400	108,000	.50	— 54,000	—16,600
45	4600	20.00	92,000	108,000	.71	— 76,700	15,300
60	5400	24.65	133,100	108,000	.87	— 94,000	39,100
75	5000	26.00	130,000	108,000	.97	—104,800	25,200
90	4050	25.20	102,100	108,000	1.00	—108,000	— 5,900
105	4100	22.10	90,600	108,000	.97	—104,800	—14,200
120	4300	18.32	78,800	108,000	.87	— 94,000	—15,200
135	4000	14.10	56,400	108,000	.71	— 76,700	—20,300
150	3300	10.10	33,300	108,000	.50	— 54,000	—20,700
165	3200	5.87	18,800	108,000	.26	— 28,100	— 9,300
180	3300	1.41	4,700	108,000	0	— 0	4,700
195	3200	— 2.82	— 9,000	108,000	— .26	28,100	19,100
210	2550	— 8.00	— 20,400	108,000	— .50	54,000	33,600
225	2650	—12.45	— 33,000	108,000	— .71	76,700	43,700
240	2800	—16.70	— 46,800	108,000	— .87	94,000	47,200
255	3200	—20.00	— 64,000	108,000	— .97	104,800	40,800
270	3000	—22.60	— 67,800	108,000	—1.00	108,000	40,200
285	3000	—23.50	— 70,500	108,000	— .97	104,800	34,300
300	3500 (2 & 3)		— 80,900	108,000	— .87	94,000	13,100
300	400 (1)	—23.10	— 9,200	108,000	— .87	94,000	84,800
315	3500 (3)	—21.10	— 73,800	108,000	— .71	76,700	2,900
315	400 (1 & 2)	—21.10	— 8,400	108,000	— .71	76,700	68,300
330	650	—17.40	— 11,300	108,000	— .50	54,000	42,700
345	2700	—12.00	— 32,400	108,000	— .26	28,100	— 4,300
0	3750	— 4.70	— 17,600	108,000	0	0	—17,600

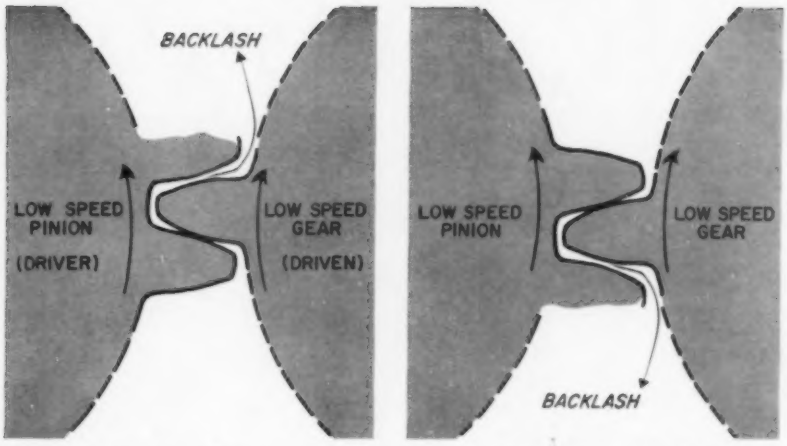

FIG. 3. **Effect of negative torque** on gear reducer. In left-hand drawing, position of low-speed pinion in relation to low speed gear for positive torque; right-hand drawing shows position of same gears under negative torque. Blacklash or tooth clearance must be designed into the gears to eliminate breakage when rotated.

MPRL = Minimum Polished Rod Load

The same fluid could be produced with a stress range as low as 20 to 30% if the well pumping rate matched fluid inflow rate, and pounding eliminated. Virtually all sucker rod manufacturers recognize stress range as one of the important factors influencing sucker rod (reversal) life.

2. Rate of change of stress is infinitely increased (i.e., the rate of change of the load is instantaneous, rather than gradual). This factor is even more detrimental to sucker rod life than (1) above.

3. Oftentimes the rods "pause" on the downstroke resulting in rod buckle and subsequent "whiplash" action. This can stress rods to near or beyond their elastic limit at the point(s) the buckle occurs, resulting in almost immediate failure at these points.

4. All of the preceding results in a greatly accelerated fatigue failure rate in the sucker rod string.

Shock on Bottom-Hole Pump

Effects on the pump due to the shock created by striking the fluid level can easily result in premature failure of balls and seats, plungers, liner columns, etc.

HOW TO STOP FLUID POUND

Oftentimes a liquid pound is present when a considerable (100 to 2000 ft) head of fluid is standing in the hole. This is due to restriction(s) in the intake system that prevent fluid from entering the pump at the same rate the well is being pumped. Shooting of the fluid level with a sonic sounder, or weighing of the fluid with the dynamometer, should determine if this is a possibility.

Obviously, eliminating the restriction will eliminate the pound and produce more fluid. Possible sources of restriction could be: in the pump valving, in pump strainer nipples, or in mud anchors with insufficient openings and/or plugged openings. Obviously, the net viscosity of the fluid being pumped also enters into the matter.

Mud anchor openings should be in the form of slots, rather than holes. Width of this slot should be slightly smaller than the diameter of the particles you wish to restrict, and the length of the slots 4 in. or so. This provides far less restriction to fluid flow (especially with the more viscous liquids) than do a multitude of holes of a diameter of the width of the slot, yet offers nearly as much restriction to particles as do the holes.

Pounding where the fluid level is at the pump can only lower the fluid level the length of the plunger stroke. Obviously, a reduction of 3 to 6 ft of fluid head should have little, if any, effect on the fluid entrance rate into the well bore. Even if it is this critical, the pump can oftentimes be lowered (remaining submerged) this short distance.

Where the fluid level in the well bore is at (or near) the pump, what is the solution to the problems caused by pounding? **Merely produce the well at the same rate as the fluid flows into the well bore.** This may be accomplished by:

A. Shortening the stroke.
B. Slowing the cycle down.
C. Off-and-on cycles where possible (electric motor with time clock installations).
D. Use a smaller plunger.
E. Any combination of the preceding that accomplishes withdrawal at the same rate as inflow. ★ ★

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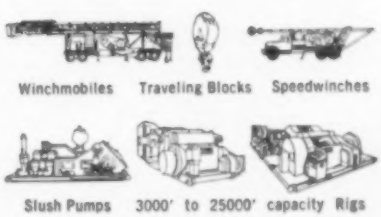


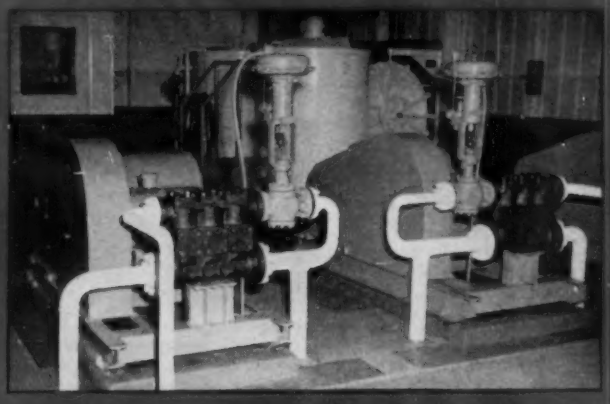
Winchmobiles Traveling Blocks Speedwinches

Slush Pumps 3000' to 25000' capacity Rigs

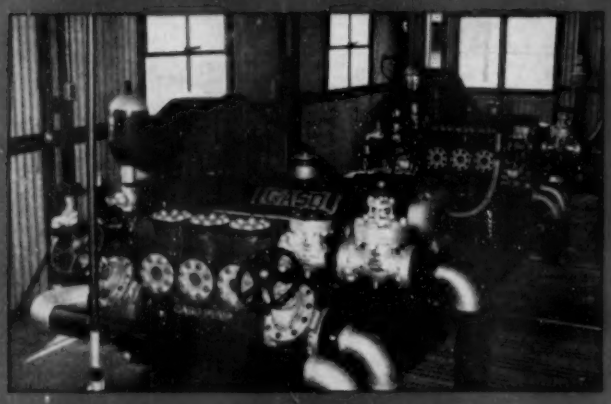
WHY YOU CAN LOOK TO THE LEADER FOR TOP PERFORMANCE IN

WATER FLOOD SERVICE

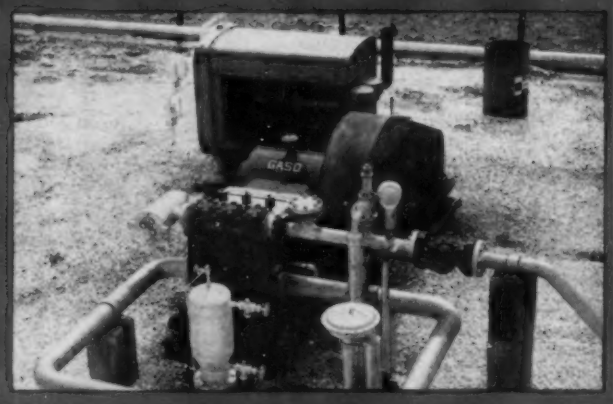
Fig. 3364 Gaso Horizontal Triplex Pump with ceramic plungers, aluminum bronze fluid end and Monel Valve assemblies, powered by 20 HP electric motor. Capacity, 850 BPD at pressures up to 1200 p.s.i.



Operating at 350 RPM, each of the three injection pumps in this installation (Gaso Fig. 3365 Horizontal Triplex Plunger pumps) delivers 1075 barrels per day at 1500 pounds discharge pressure.



Only service required on this Gaso Fig. 3466 Horizontal Triplex Plunger pump in discharging 1½ million barrels of salt water was the replacement of the plungers — at a total cost of $73.89.



Whatever the need, you may depend on Gaso for pumps and fittings best suited to the conditions. Illustration shows a Gaso Fig. 3671 Pump in salt water disposal service in Louisiana.

Where else but from the leader can you buy pumps embodying so much experience, so many advances and refinements, such demonstrated operational efficiency and maintenance economy? Where else can you find so complete a line and such cooperative pump service specialists as Gaso distributors? When the selection of pumps is governed by the yardstick of value, the logical choice is GASO Pumps. Our engineers welcome the privilege of applying their specialized experience to any problem involving water flood pumping service.

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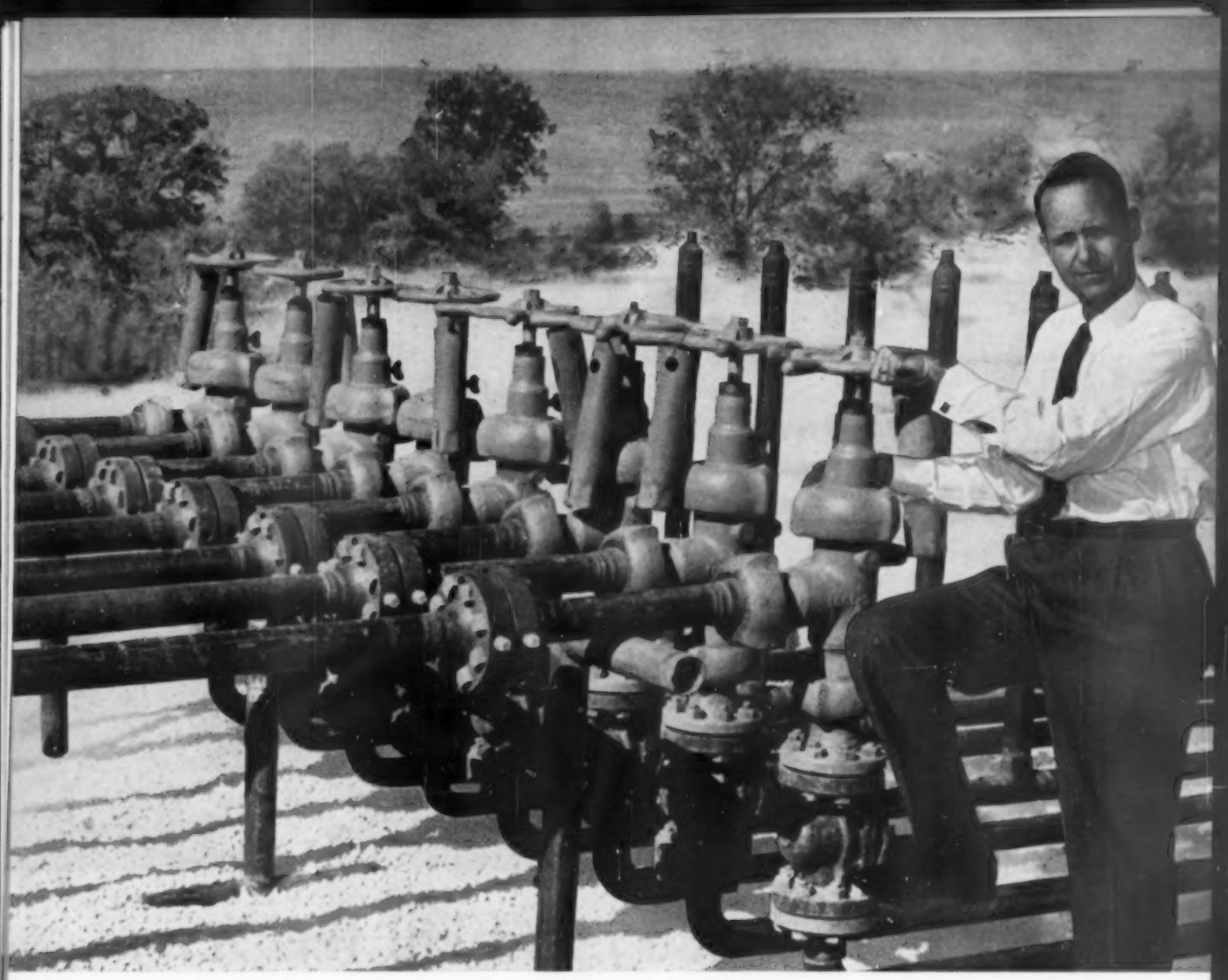
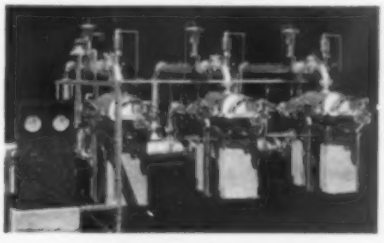


How an Oklahoma Operator Dried Up Valve Trouble On a Big Waterflood

This is a view of the water injection manifold on the Naval Reserve Field waterflood project in Oklahoma. In the beginning, this operation was plagued with valve troubles . . . until UNIBOLT Adjustable Valves were installed.

As is the case in many waterflood operations, the raw water at Naval Reserve is corrosive and abrasive. Cavitation of the fluid as it passes thru the valve has an eroding effect on the valve seats. However, since the UNIBOLT Adjustable Valve employs both the right design and the right materials, it has practically put an end to this Operator's valve troubles. For example, the stem and seat are of special analysis chrome steel, honed to mirror smoothness. And the stem is guided to the seat thru an extra long pilot that exactly centers it to insure a streamlined flow. Manufacturing details, perhaps, but added to dozens of similar features they add up to perfection and the one valve that is best suited for waterflood injection manifold and similar troublesome services.

Planning a waterflood or having valve troubles in your present system? Talk to the UNIBOLT representative in your area and get all the facts about this Adjustable Valve.



Three self-cleaning Jet Filters, manufactured by Thornhill-Craver Co., on a waterflood operation near Odessa, Texas. These Filters automatically clean raw injection water to any desired degree, even to sub-micron particle size.

THORNHILL UNIBOLT CRAVER CO.

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Even heavy crude can't kill this foam!

AFROX® 200 FOAMS SATURATED SALT WATER AND OIL

AFROX 200 is extending the advantages of air and gas drilling to a wider range of hole conditions because it foams where other foaming agents fail. AFROX 200 was formulated specifically to combat salt water invasion. Extensive field tests proved its ability to handle heavy intrusion and, in addition, showed its performance to be virtually unaffected by the presence of oil.

Foamed in 60% Oil In the application pictured above AFROX 200 was used after heavy crude and salt water had matted cuttings in the annulus. A slug of 6 gallons of AFROX 200 in 12 barrels of water was used to foam out fifty to sixty barrels of oil, water and cuttings. The fluid in the hole was estimated to be 60% oil.

Two AFROX Formulas AFROX 200 foams all water containing more than 5% salt and in the presence of oil. Oil-bearing fresh water is easily foamed by injecting AFROX 200 in a salt water solution.

AFROX 100 is designed to foam relatively fresh and oil-free water. It may be used where the salt content is less than 5%.

AFROX Foaming Agents are products of the Aquaness Department of Atlas Powder Company. They are distributed by leading mud companies and are available in all areas where air and gas drilling techniques are employed.

Write for new AFROX brochure, which gives complete information on the use of AFROX foaming agents.

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easier handling around the rig . . lighter weight without sacrificing strength.

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less weight but more than adequate capacity for today's increased horsepower requirements.

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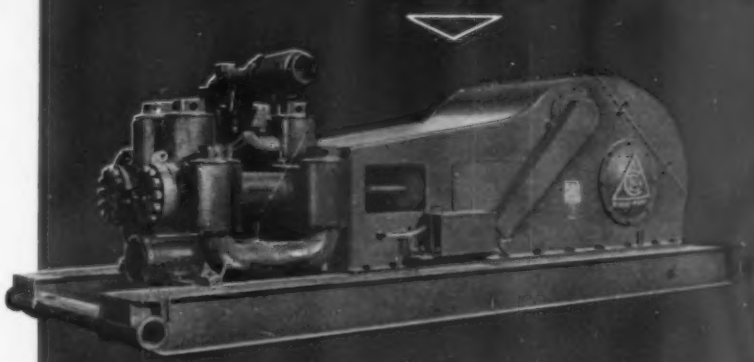
Check these features. See why overseas operators, drilling in remote areas, have more confidence in Continental pumps. Regardless of your operation . . local or worldwide . . buy Continental pumps and take advantage of their ability to pump more mud at lower cost.



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DA-700—Maximum input . . 700 hp @ 80 rpm
D-550—Maximum input . . 550 hp @ 80 rpm
D-375—Maximum input . . 375 hp @ 70 rpm
D-225—Maximum input . . 225 hp @ 70 rpm
D-125—Maximum input . . 125 hp @ 85 rpm

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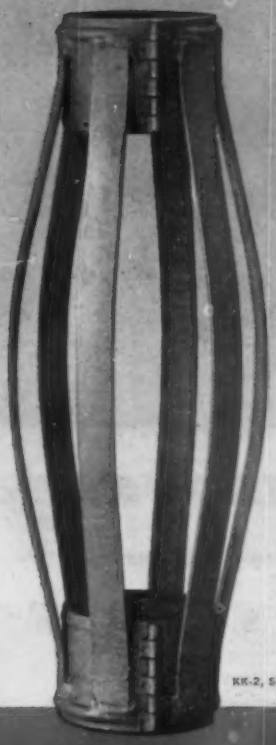

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Test Probe For Mohole Drills in 11,700 Ft Water

THE DRILLING BARGE CUSS I recently successfully drilled in the deepest ocean depths ever achieved and opened new vistas for exploring the earth and its origin.

Working in 11,700 ft of water off the coast of Baja, California, the vessel drilled both a 110 and 234 ft hole in the ocean floor, bringing up the deepest specimens of the earth's crust ever extracted from beneath the ocean. At deep ocean depths, the earth's crust is believed to be the thinnest and should reveal the most information on the inner earth's composition and history.

In this experiment the only connection between the drilling vessel and the ocean floor was 11,700 ft of 4½-in. drill pipe, with no conductor pipe or other lateral support. A diamond bit performed the actual drilling and salt water served as the only drilling fluid, Robert F. Bauer, president of Global Marine Exploration Company, commented.

While operating, the drill pipe was suspended from a 98-ft derrick through a large centerwell in the barge. An engine-powered rotary table drove the pipe as on other standard rigs.

It remains to be seen how much additional resources that rest untapped beneath the ocean, and this achievement should give some light as to what can be expected.

The unprecedented deep-water drilling took place as part of the Mohole scientific project, which ultimately aims to probe through the earth's crust and into its mantle. The project off Baja was designed as a test in deep water of the drilling techniques from a floating vessel.

This successful drilling was at ocean depths some four times deeper than ever before attained. Earlier, as a part of Mohole experiments, the CUSS I had drilled at depths of 3000 ft off La Jolla, California. Before that, the deepest ocean drilling from a floating vessel had been in about 400 ft of water.

Among the major modifications are a guide shoe or curved funnel which is installed immediately beneath the drilling rig's rotary table some 10 ft into the water, and a tapered casing — hollow in the center — fastened to the landing base at the ocean's floor. Normally, the CUSS I is held in place by anchors during drilling. For the Mohole experiments, however, the barge is maintained in position by four steerable 200-hp outboard motors which are controlled according to radar and sonar sensings off fixed buoys. ★ ★ ★

BAROID OIL MUD SOLVES WATER-

Baroid Field Report: Los Angeles County, California **This case history exemplifies the application of one**

MUD PROBLEM:
To drill and complete in water-sensitive pay sands

WELL DATA

LOCATION: Inglewood Field, Los Angeles County, California
TOTAL DEPTH: 9,390'
BOTTOM HOLE TEMPERATURE: 275 F to 300 F

CASING PROGRAM

SIZE, INCHES O.D.	DEPTH SET, FEET
16"	550'
10¾"	3,000'
7"	8,975'

MUD ADDITIVE PROGRAM

550 to 3,000'	AQUAGEL*—caustic soda—CARBONOX* emulsion mud
3,000' to 7,400'	Water-base emulsion mud containing 10 volume percent oil, HYDROCARB* and TRIMULSO*
7,400'	Displaced the oil-in-water-emulsion mud with Baroid Oil Mud
7,400' to 9,390'	Drilled with Baroid Oil Mud containing INVERMUL*, PETROTONE** and DURATONE**

TYPICAL MUD PROPERTIES OF BAROID OIL MUD

Depth, ft.	7,414	8,150	9,390
Weight, lb/gal	10.8	11.6	12.2
Viscosity, sec	95	115	131
Filtrate, ml (oil)	0.0	0.0	0.5
Oil, % by volume	45	44	42
Solids, % by volume	15	21	22
Water, % by volume	40	35	36
Electric Stability, volts	220	230	220

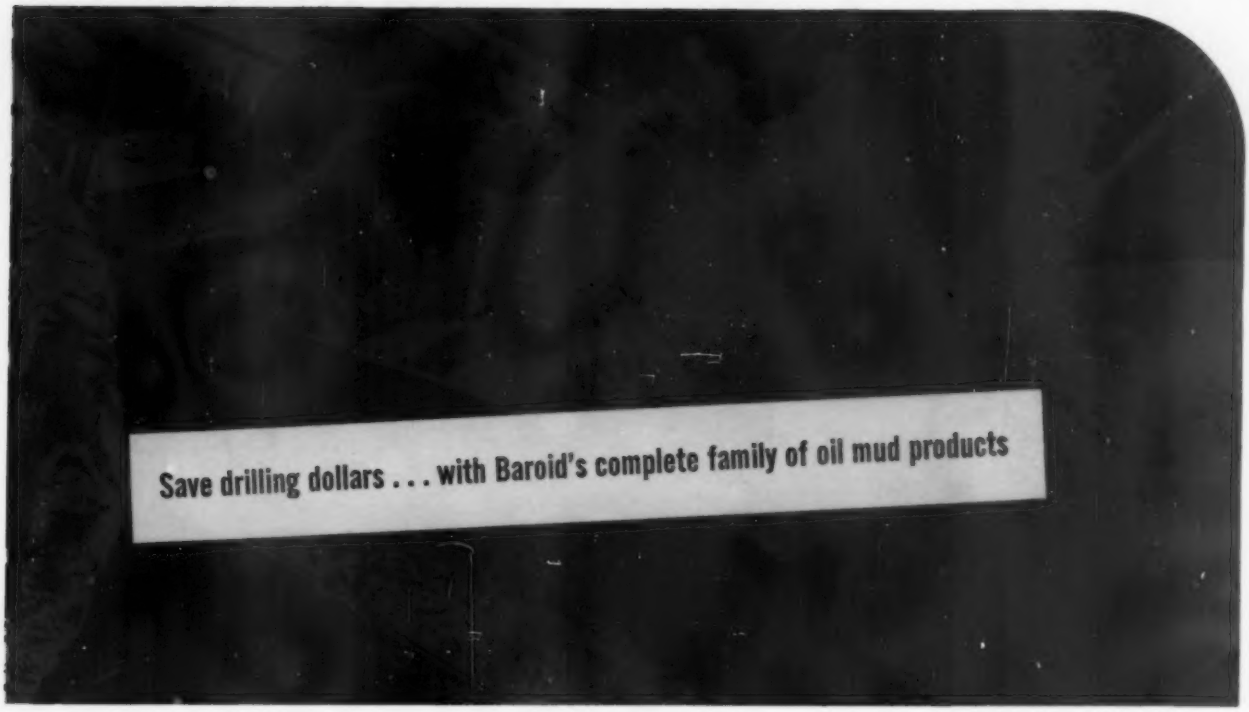
DISCUSSION: Water-sensitive formations and high bottom-hole temperatures below 7,500 feet in the Inglewood Field, Los Angeles County, California present a problem in the selection of a drilling mud. Formation damage is attributed to the filtrate from conventional water muds. To prevent formation damage and minimize hole enlargement Baroid Oil Mud was selected to drill the bottom 2000 feet of hole.

SOLUTION: The Baroid Oil Mud selected was pre-mixed with INVERMUL and DURATONE and used to displace the water mud at a depth of 7,400'. No difficulty was encountered during the displacement. Water mud incorporated into the INVERMUL-DURATONE Oil Mud did not alter its flow properties. To prevent settling of BAROID* as bottom-hole temperature increased (275 F to 300 F), the oil mud was treated with 2 lb/bbl PETROTONE. Filtration was maintained at 0.0 to 0.5 ml. all-oil, eliminating any possibility of water-wetting the formations.

*AQUAGEL, bentonite; CARBONOX, thinner; HYDROCARB, alkaline thinner; TRIMULSO, surfactant; INVERMUL, emulsifier; DRILOIL, oil mud concentrate; and DRILTREAT, stabilizer; are Registered Trademarks of Baroid Division National Lead Company.

**PETROTONE, suspending agent, and DURATONE, filtration stabilizer, are Trademarks of Baroid Division National Lead Company.

BAROID--*Still Pioneering Drilling Mud Research • Engineering • Marketing*



SENSITIVE PAY SAND PROBLEM

type of Baroid Oil Mud used to solve this particular problem.

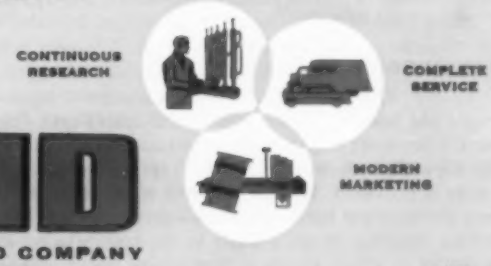
The Baroid family of oil mud products are INVERMUL, DURATONE, PETROTONE, DRILOIL* and DRILTREAT*. These products allow the operator to select an oil mud having properties suitable for the drilling problem. Such properties can also be modified by treatment if necessary. This approach has long been used in the selection and treatment of conventional drilling muds but is new to oil muds. This new approach to oil muds has resulted in their successful use for drilling, coring, completion, perforating, gravel packing, packer fluids, freeing stuck drill pipe, and for fishing.

In this case history in Los Angeles County, California, a Baroid Oil Mud was selected as the practical solution to the problem of drilling and successfully completing water-sensitive pay sands. At 7,400 feet an INVERMUL-DURATONE Oil Mud was used to displace the damaging water mud. This oil mud was treated with 2 lb/bbl PETROTONE to eliminate any possibility of settling of weight material as bottom-hole temperature increased. Drilling was trouble-free and completion successful.

INVERMUL, a free-flowing powder, the basic ingredient in this Baroid Oil Mud is an active, readily oil-dispersible emulsifier that stabilizes the emulsion and protects productive formations by controlling filtration.

PETROTONE is a dry powdered colloid that imparts solids-suspending properties to all types of oil muds — is easily mixed — treatment is nominal in cost. The usual amount added is 1 to 5 lb/bbl of oil mud. PETROTONE is stable at the highest bottom-hole temperatures presently encountered in drilling.

DURATONE, a unique organic colloid, controls filtration of all types of oil muds at the highest bottom-hole temperatures. The development of DURATONE and PETROTONE, as companion products to INVERMUL, has diversified and extended the application of oil muds. This is another example of how Baroid's customer-oriented program of research and engineering saves you drilling and completion dollars and keeps your operations on schedule.



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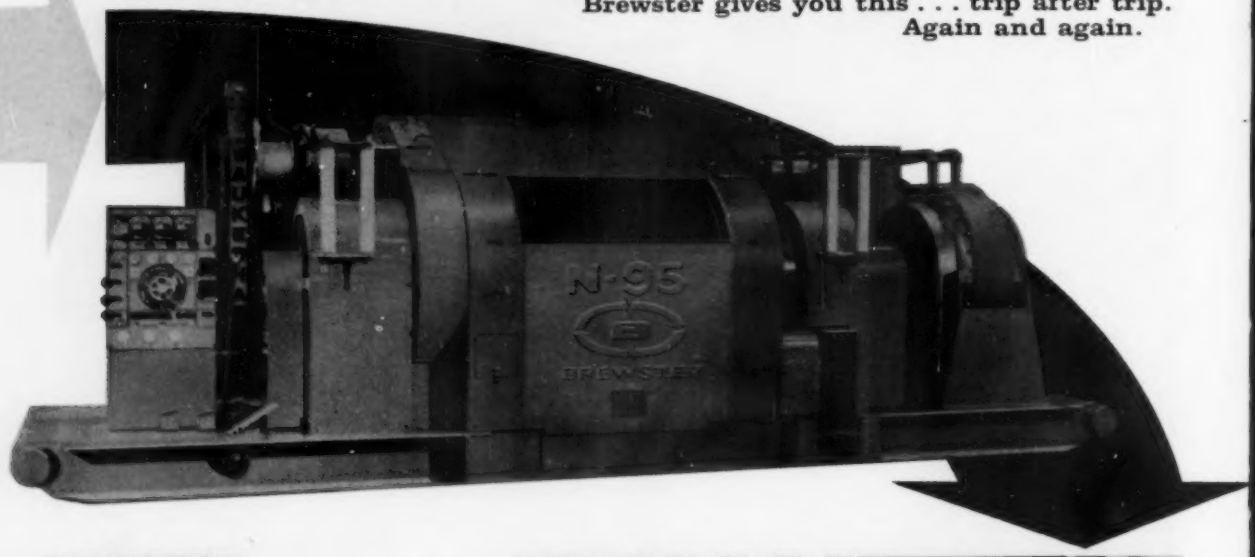
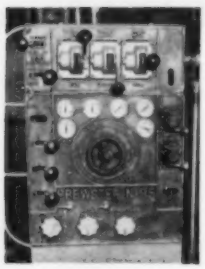




BREWSTER

DEPTH RATING . . . . . 12,000' to 14,000'

TOTAL HORSEPOWER 1,200

Torque Converter, Fluid Coupling or Mechanical Drives. Heavily Shafted and Chained, the N-95 Drawworks Will Accept the Full 1,200 H.P. at the Drawworks Input Shaft.

DRAWWORKS

The Brewster N-95 is a single package side skidded drawworks. Integrally mounted on the main skid are the control panel, built-in transmission and hydromatic brake with all piping and water level tank. When placed on the drilling floor the drawworks requires the connection of only two chains to be ready for operation . . . one chain from input shaft to the compound . . . one chain from rotary drive to the table.

High and low, rotary and input clutches are latest design, high capacity, air-actuated Twin-Disc plate clutches. Clutches are mounted outboard for ease of servicing. Shaft assemblies are complete units and may be removed in the field for maintenance or service. All chains and high speed bearings are oil pressure lubricated. Drum shaft bearings are grease lubricated.

TRANSMISSION

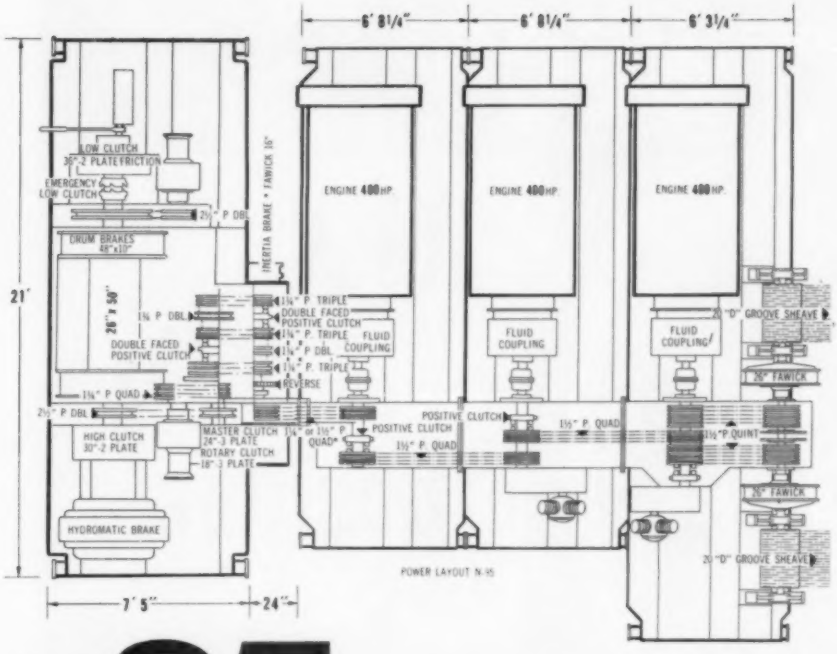
The compact chain transmission is enclosed in an oil-tight housing in the rear of the drawworks frame. It features Brewster's field-proved graduated-speed design with four forward speeds, each a 38% speed increase. A gear reverse is provided. When combined with the high and low drum drives, eight forward and two reverse speeds are available for hoisting. A third shaft in the transmission enables the driller to select a high or low rotary speed independent of the hoisting speed. All transmission clutches are air-actuated and air-interlocked to prevent engagement of opposing clutches.

COMPOUND

The N-95 is available with two types of compounds, sectional and heavy duty box type. Single and split level arrangements are available. Engines are coupled to the compound through Fawick air clutches which also serve as flexible couplings and act as engine disconnects when moving the rig. When fluid couplings or torque converter drives are used, engines can be coupled to compound by a flexible coupling. Compounding clutches are gear-tooth type and can be actuated singly or in groups giving a wide variety of compounding arrangements.

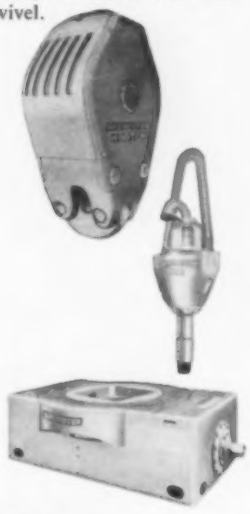
PUMP DRIVES

Single or dual pump drives are mounted at the rear of the compound. They are connected to the compound through Fawick air clutches. Air controls at the driller's position permit the drives to be used singly or together and at different speeds. Mounting of both pump drives at the rear of the compound simplifies rigging-up and manifolding . . . eliminates the need of idlers or notching the substructure.



POWER LAYOUT N-95

Brewster Matched Drilling Equipment for the N-95 Drawworks includes the Model 400 Traveling Block, the RSH-22 Oil bath Rotary and the 7-SX Oil bath Swivel.



n95 ROTARY RIG DRAWWORKS

PERFORMANCE CHARACTERISTICS

Transmission Speeds	*Cathead Shaft R.P.M.*	*Rotary Drive Sprocket R.P.M.*	*Low Speed Drum Drive Line Speeds And Pulls*	*High Speed Drum Drive Line Speeds And Pulls*
Low	109	216	326′/Min. 88,500 lb.	1,235′/Min. 24,130 lb.
Second	151	300	457′/Min. 67,100 lb.	1,710′/Min. 18,490 lb.
Third	210	470	632′/Min. 48,600 lb.	2,380′/Min. 13,290 lb.
High	292	653	879′/Min. 34,900 lb.	3,310′/Min. 9,550 lb.

Line pulls based on 1,050 h.p. with 83.3% Rig eff.

BRAKES

Brakes are full 325° wrap, having 1⅛" x 10" linings on 50" diameter drums, with a total braking surface of 2,836 square inches. Brake flanges are bolted to the main drum and are of the circulating water-cooled type. The compound equalizing and self-energizing brake design provides maximum holding power with little manual effort. Provision has been made to cradle mount a hydromatic or dynamatic brake on the side opposite the driller.

CONTROLS

All controls for the N-95 drawworks, compound engines and pump drives are air-actuated. The simplified control panel is mounted as an integral part of the drawworks package. Its convenient location permits the driller to have a full view of the drum and all operations on the drilling floor. Controls provide a wide selection of engine compounding arrangements. Transmission clutches are operated by turning a single hand wheel to the selected speed.

PORTABILITY

The N-95 has been designed for maximum ease in rigging down and moving. The entire rig can be moved in four over-the-road packages when the 3-engine compound is used. When the 2-engine compound is used, only three packages are required. The drawworks is separated from the compound by disconnecting a single chain and unbolting one guard. The controls, transmission, rotary drive and hydromatic brake are mounted on the main drawworks skid and moved as a single load.

LUBRICATION

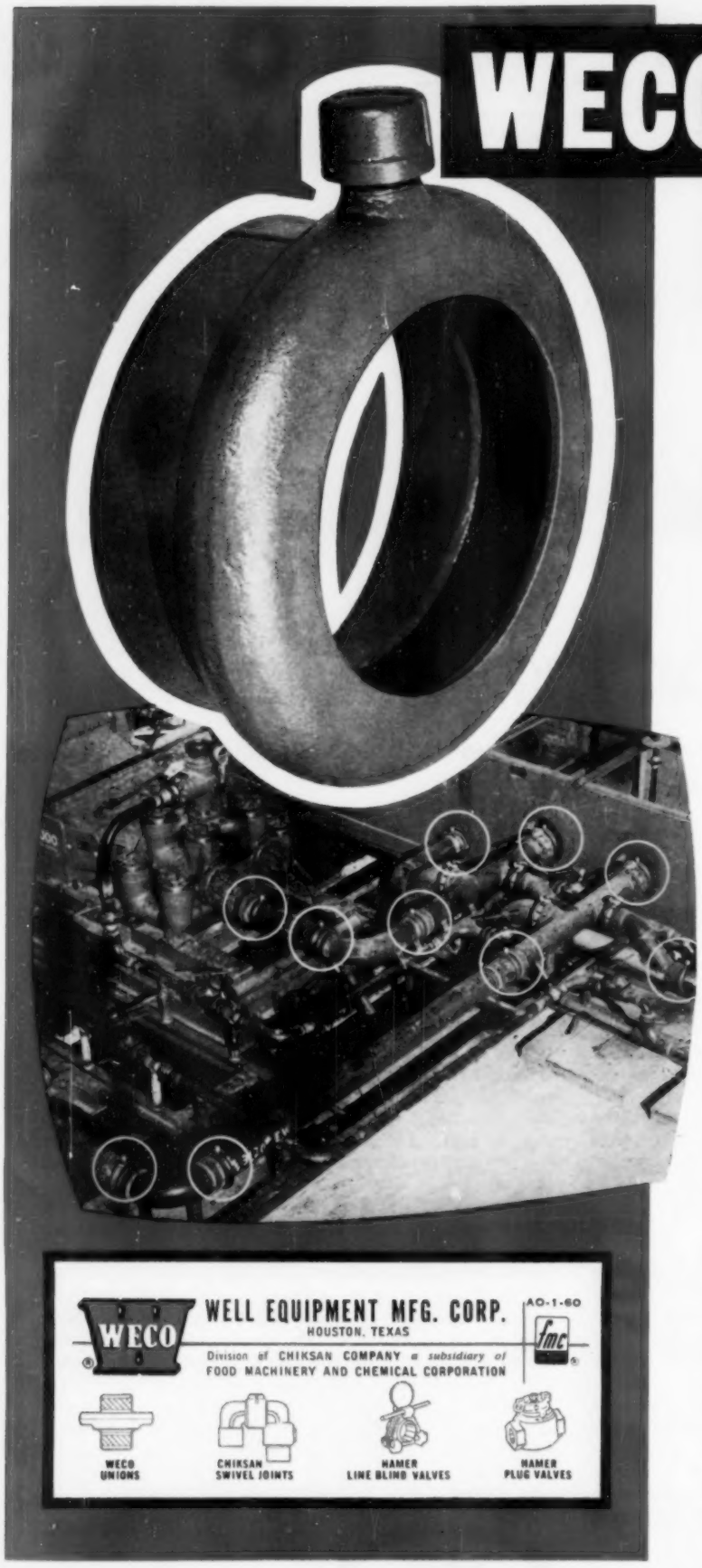
All chain drives in the drawworks, transmission and compound are oil bath and oil pressure lubricated. They are enclosed in oil-tight housings. All main shaft and sprocket bearings are pressure oil lubricated and drum bearings are grease lubricated. An abundant supply of filtered oil is supplied by separately driven oil pumps. Oil cooling coils are available for the compound.

For more details ask your Brewster dealer *or write* THE BREWSTER COMPANY, INC.

THE BREWSTER COMPANY, INC.
P. O. BOX 1095, SHREVEPORT, LOUISIANA

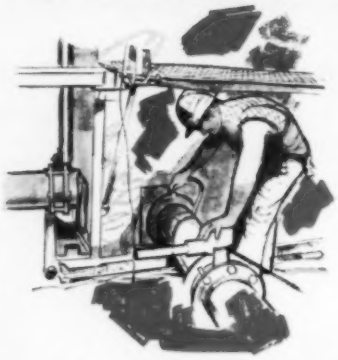
PRODUCTS OF CREATIVE ENGINEERING

WECO AIR-O-UNION



fast
easy
positive

and it seals with a shot of air



No bolts, nuts and wrenches are required to make-up and seal low pressure lines when you use the WECO Air-O-Union. Just a shot of air expands and seals the inflatable tube around the pipe. And break-out is just as easy. Deflating the tube releases the seal.

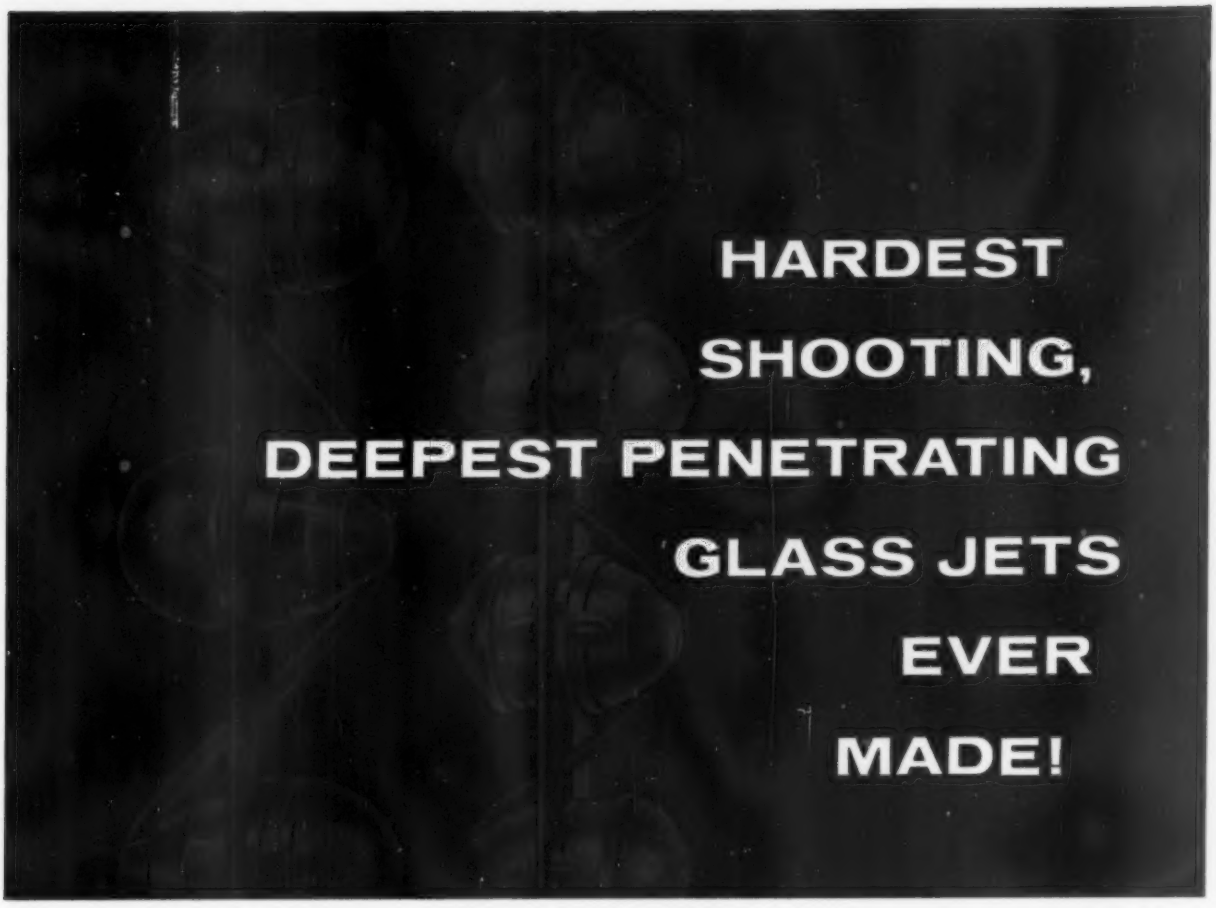
With WECO Air-O-Unions welded into place on your mud tanks, suction and return lines and fittings, mud systems are set up with less time, trouble and cost than ever before. Switch to low cost, time-saving, simple WECO Air-O-Unions on all of your low pressure lines. They are available in sizes 4" through 16".

WECO Air-O-Unions are available from your supply store . . . or ask your WECO or Chiksan representative.

WELL EQUIPMENT MFG. CORP.
HOUSTON, TEXAS
Division of CHIKSAN COMPANY *a subsidiary of* FOOD MACHINERY AND CHEMICAL CORPORATION

AO-1-60

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD



OVER 9″ OF PENETRATION IN HARD BEREA SANDSTONE

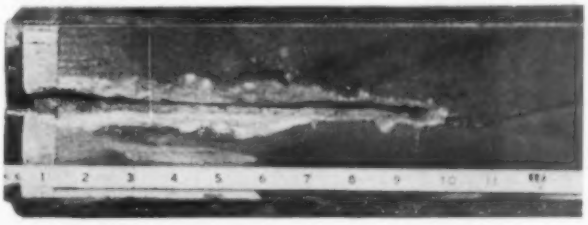
Two, more powerful, deeper penetrating Glass Jet Units are now available from McCullough. They are the improved 25-gram Standard Casing Glass Jets to perforate 4″ OD casing and larger and the improved 35-gram Super Casing Glass Jets for 5½″ OD casing and larger. Both are run in flexible Steel Strip Carriers.

In tests conducted in standard Berea Sandstone targets, penetration for each size was greater than ever before achieved – more than 9″ in these very hard targets and with excellent well flow index.

McCullough Glass Jets are the only expendable jet charges that are relatively junk free. When fired they disintegrate into a harmless powder of silicon and lime. No carrots are formed. Fragments of junk, usually associated with other expendable jet perforators, are eliminated. The Steel Strip Carrier is removed from the well after the gun is fired on the electric wire line.

For deeper penetration – peak production – use improved McCullough Standard or Super Casing Glass Jets on your next job.

The 25-gram Standard Casing Glass Jet is available in 3¼″ OD and 3¾″ OD gun diameters. The 35-gram Super Casing Glass Jet is furnished in 4″ OD and 5″ OD diameters. Perforators may be any length required to perforate several intervals on one run in the well. This is accomplished by leaving blank sections in the length of carrier where perforating is not required.



Standard Berea Sandstone target perforated by 25-gram improved Standard Casing Glass Jet at ½″ clearance. Average penetration of a series of tests – 9.312″. Average entrance hole size – 0.375″. Pressure rating – 20,000 psi. Temperature rating – 300°F.

McCullough
TOOL COMPANY
Los Angeles • Houston • Edmonton
Cable Address: MACTOOL

FOR FURTHER INFORMATION ON
ADVERTISED PRODUCTS, SEE READER SERVICE CARD

Unaflo oil-well cement,

CEMENTING DATA

Job — Hattie S. Welch #1, Jefferson Davis Parish, South Louisiana

Drilling Contractor — The Bullard Drilling Co., Inc., Houston, Texas

Owner — Austral Oil Company Incorporated, Houston, Texas

Job #1 — 7⅝" O.D. casing string set at 10,277' in 10⅝" hole, cemented with 500 bags UNAFLO cement plus 6% gel (slurry wt. 14.7 lbs/gal.) followed by 200 bags UNAFLO cement neat, (16.3 lbs/gal.). Drilling mud wt. 13.4 lbs/gal. Schlumberger temp. log 181° F. Est. static BHT 213° F.

Job #2 — 5½" O.D. liner, 2,146' long, bottomed at 12,000' in 6¾" hole cemented with 320 bags neat UNAFLO cement. Drilling mud wt. at cementing 16.4 lbs/gal. Schlumberger temp. log 255° F. at 12,160'. Est. static BHT 265° F.

Job #3 — 5½" O.D. full casing string tied to top of 5½" O.D. liner, using liner to casing coupling with 100 bags neat UNAFLO cement.

compatible with various additives...

UNAFLO oil-well cement is successfully used neat or with various types of additives in more and more cementing operations. For cementing casing or liner, squeeze cementing, plug-backs or recementing, UNAFLO cement slurries pump easily and set hard to provide an adequate seal. Its retarded set sustains high initial fluidity despite high temperatures and pressures. This allows time for proper placement plus a margin of safety for delays or emergencies.

For more information, write Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

Universal Atlas Cement
Division of
United States Steel

U-163

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"A great step forward with your Planetary Gears, Big Bearings and Cylindrical Crossheads."

— J. K. Butler

WHELAND PLANETARY
HP-16000 PUMP
Duplex Power Slush Pump
7¾" x 16", 600 H.P. at 65 RPM

OIL PRODUCTION MAINTENANCE, INC.
7440 CHOCOLATE BAYOU ROAD -- P. O. BOX 14291
HOUSTON 21, TEXAS
August 31, 1960

Mr. Gordon P. Street, President
The Wheland Company
Chattanooga, Tennessee

Dear Mr. Street:

Our Wheland Planetary Pump is giving us increased penetration and good savings on bits. We know from more than 18 months of constant operation on 10,000 Ft. wells that our savings are substantial.

We have kept an accurate record on operating costs and all maintenance costs and are especially impressed by the low cost of fluid end expendables. The HP-16000 Pump has constantly operated near its rated capacity on more than 200,000 feet of hole in the Texas Gulf Coast Area.

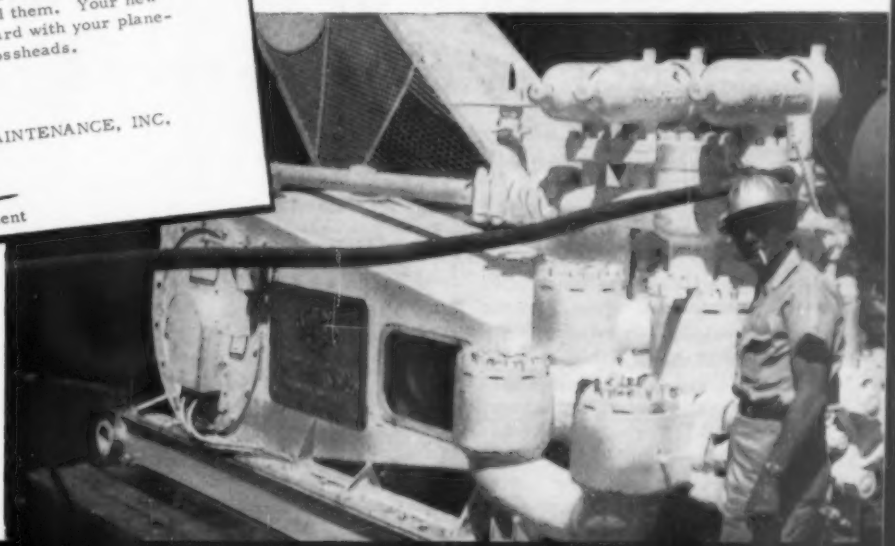
We are now operating Wheland HP-18000, HP-14000, and HP-16000 Pumps and are glad to recommend them. Your new HP-16000 Pump design is a great step forward with your planetary gears, big bearings and cylindrical crossheads.

Yours very truly,

OIL PRODUCTION MAINTENANCE, INC.

J. K. Butler

J. K. Butler, President



Wheland HP-16000 Planetary Pump owned by Oil Production Maintenance, Inc., on location in the Gulf Coast area.

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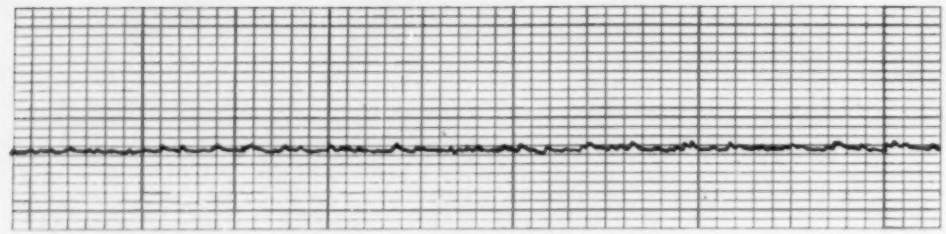

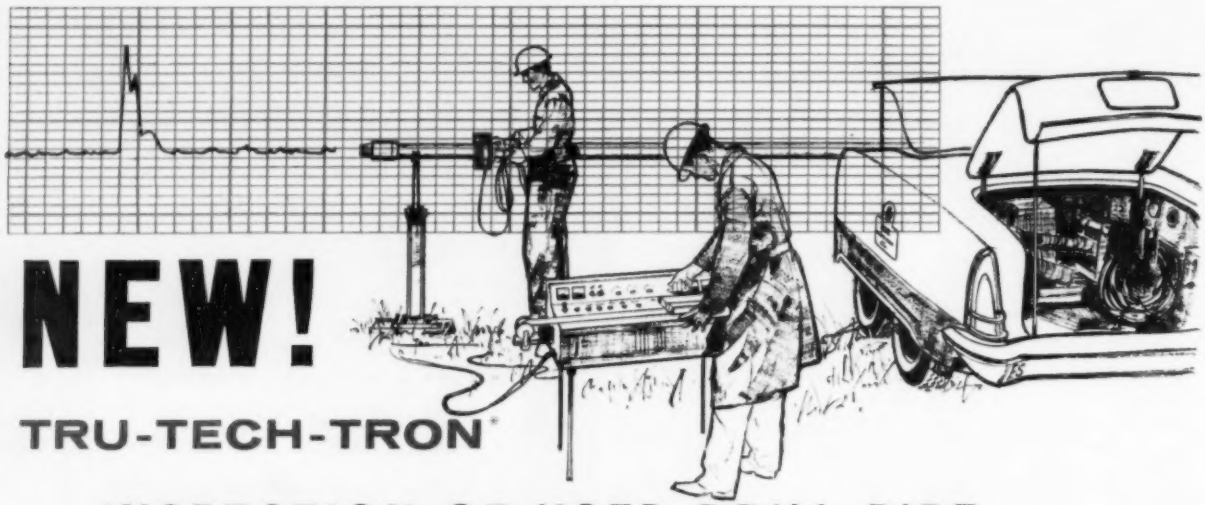

NEW!

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INSPECTION OF USED DRILL PIPE

RECORDS ONLY DEFECTS...NO "NOISE"

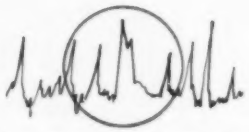
Rust, mill scale, and other common pipe surface conditions, have a tendency to create "noise" or "grass" which can be recorded during electromagnetic inspection of drill pipe. If this noise is recorded, it can easily be misinterpreted as harmful defects, or it can obscure the recording of an actual defect.

UNISCO's† new TRU-TECH-TRON inspection equipment screens out undesirable noise and produces accurate, easy-to-read defect recordings. When an indication appears on the TRU-TECH-TRON log it represents an *actual* defect. If the pipe is free of defects, *no* indications are recorded.

This superior method of electromagnetic inspection records only the most SEVERE defect at any one point—even when this defect lies in the same diametrical plane with other defects of greater and lesser magnitudes. There is no adding or compounding of defect signals to cause false indications to appear on the TRU-TECH-TRON log.

A self-monitoring feature has been built into TRU-TECH-TRON to assure that each detector is working properly at all times. You learn the true condition of each length of pipe when you use TRU-TECH-TRON. You prevent wasting good material and protect yourself against costly failures.

An 8-page, 2-color brochure which describes TRU-TECH-TRON inspection is available to you now—ask for your copy today or write Department 7 P. O. Box 66669, Houston 6, Texas.



When "noise" or "grass" is not controlled, defect recordings could be overlooked.

TRU-TECH-TRON produces positive recordings of defects — noise is eliminated.

UNIVERSAL INSPECTION & SERVICE COMPANY

A Division of Atlas Bradford Company

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AFFILIATED COMPANIES

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*TRU-TECH-TRON is a service mark of Universal Inspection & Service Company.

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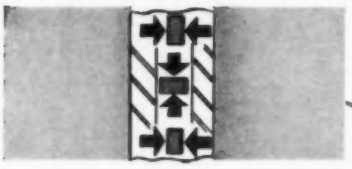
NOTHING excels this unit for AUTOMATIC PRESSURE CONTROL WHILE DRILLING!

THE SHAFFER ROTATING BLOW-OUT PREVENTER AND STRIPPER

has no equal in modern pressure control protection because no other equipment is so versatile... so simple ...*so dependable!*

It *automatically* seals off around the drill string when the tools are in the well. You can run drill collars, tool joints, subs and drill pipe through it—going in or coming out—and *the Stripper Rubber maintains its pressure-tight seal throughout all drilling and pipe-changing operations.* Pressure emergencies simply cannot happen too fast for this unit. It is always sealed off until the drill string is removed from the well.

Check over the important features outlined below. You'll find the Shaffer Rotating Blowout Preventer and Stripper ideal for every important drilling requirement!

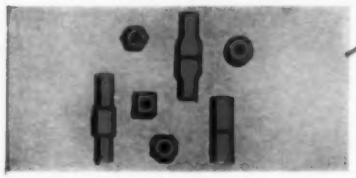


WEAR-FREE!

The Stripper Rubber rotates with the kelly—not one inside the other. Therefore, flexing and wear are negligible as the drill string rotates. Note that separate thrust and radial bearings (each pre-packed with heat-resisting lubricant) resist any combination of bearing loads!

SIMPLE!

To pass bits, reamers and other abnormally-large diameter tools through the unit, simply lower the tools through the body until the rotating assembly seats in place. Then rotate the bonnet 1/6 turn. This locks the entire internal mechanism in place, to provide a continuous seal against well pressures.



VERSATILE!

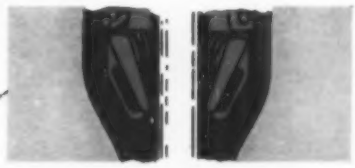
All the varying diameters in the drilling string—drill collars, tool joints, subs and drill pipe (whether upset, flush or coupled)—readily pass through the Stripper Rubber without loss of pressure—and without any manual adjustments. Even the kelly—whether square, hexagon or octagon—is sealed off *automatically!*

CONTINUOUS!

The Stripper Rubber expands and contracts automatically to fit all normal elements in the drill string (excepting only bits, reamers and similar large diameter tools). No hydraulic, pneumatic or mechanical pressure need be applied. No accessory equipment is required!

COMPACT!

Unit is amazingly compact in all dimensions—can be installed in unusually "tight" locations. Even flow connections are built-in—no space-wasting spools are required!



TROUBLE-FREE!

A barrier of flexible steel latches protects the Stripper Rubber against damage while varying diameters pass through the unit. This expandable steel barrier also protects the rubber from extrusion under high well pressures!

TWO TYPES—Use the Type 50 for drilling through 10¾" casing and larger... Use the Type 51 for slim hole drilling, production and rework jobs. Both have the same basic features!

For further details see your nearest Shaffer representative, or write direct!

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4. Minimized hydrostatic pressure on formation when running bit in hole.
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what makes an acid treatment profitable?

In Oklahoma, a Dowell-engineered acid treatment gave the desired production increase, yet cost $1350 less than treatments used on other wells in the same field.

In Utah, Dowell-engineered acidizing boosted well production from 34 to 450 bopd in a field where other acid treatments had broken through to water.

In South Texas, a Dowell-engineered acid treatment opened up a salt water disposal well where earlier treatments had failed.

What single difference made these treatments more successful than earlier efforts?

The one difference that towered above all others is engineering. Dowell designed each treatment to fit well conditions and the operator's needs. The result was extra profit.

Dowell is well-qualified in the kind of engineered treatment design that results in excellent profit increases.

Dowell developed the Acid Guide* — a new method for designing treatments and predicting probable results. Several thousand successful acid jobs have been designed with the help of the Acid Guide within the past two years.

Dowell has an unsurpassed fund of data on formation and fluid characteristics from many fields. This information is necessary for scientific treatment planning but it is often not available from individual operators.

Dowell has a large variety of acid additives as well as collateral products and services to improve results from acid treatments.

To summarize, Dowell has the experience, the information, the acid additives, the collateral products and services, the technically-trained personnel and the laboratory facilities to design engineered acid treatments. Results have been high success ratios and satisfactory payouts on investments.

There *is* a difference in acidizing services. Dowell services and products are offered from more than 150 offices and stations in the United States, Canada, Venezuela, Argentina, Germany, France and the Sahara area. Dowell, Tulsa 1, Oklahoma.

*DOWELL SERVICE MARK

SERVICES FOR THE OIL INDUSTRY

DOWELL

DIVISION OF THE DOW CHEMICAL COMPANY

Oil Well Cementing Practices and Materials

PHIL C. MONTGOMERY and DWIGHT K. SMITH, *Halliburton Company, Duncan, Oklahoma*

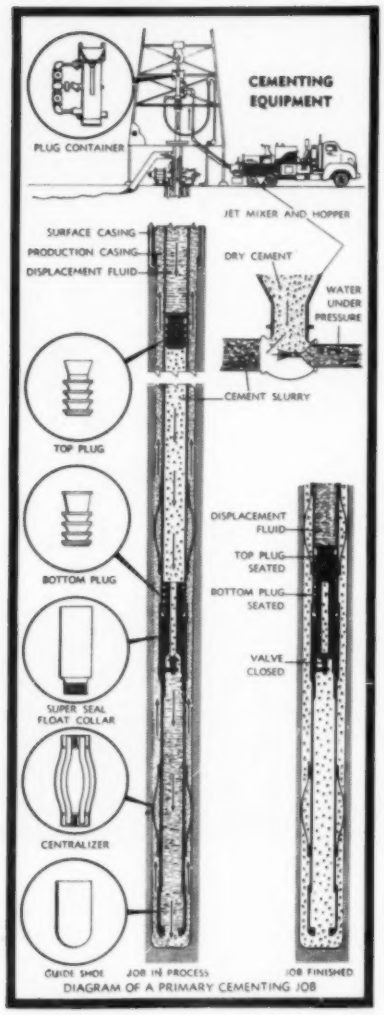

FIG. 1. Primary cementing is referred to as the original cementing operation which is performed immediately after the pipe or casing has been run in the hole. This basic principle is varied in many ways and with many materials to perform the many cementing operations common today.

CEMENTING OPERATIONS today are precise and highly complex. Like most oil field operations, cementing practices are always changing rapidly and there is seldom available, in one source, a comprehensive review or compilation of pertinent information of such a broad subject as oil well cementing. Over 1700 articles have been written on the subject since its beginning several years before the turn of the century.[1] The authors have reviewed nearly all of these 1700 articles and have searched the voluminous files of their own company in an effort to make this discussion as complete as possible.

This discussion has to do with equipment, materials, and services that are available to the oil industry, the oil operator, and the drilling contractor, including the terminology used in the processes. No attempt has been made to standardize these terms; they are given as used in different oil fields.

The complete report will be presented in two parts. This, the first, covers the subject of cementing methods and practices. The second part, to be published in next months's issue, will deal with cementing materials and additives.

It is difficult to imagine the drilling and completion of a well without the benefit of oil well cementing, but many wells had been completed before the first cementing job was reported in some Appalachian operations prior to 1900 and in Pico, California, in 1883. Since that time oil well cementing has become an elaborate and highly technical service without which many modern completions would be impossible.

The first cementing operations used the dump bailer method of placing cement. Later, cementing through tubing and casing became common, followed by the use of more cement in individual wells due to various field conditions such as depth and hole size. These conditions required development of materials and tools which eventually brought about the many types of cementing jobs we use today.[2]

The basic principal of oil well cementing is the process of displacing cement slurry down the casing, tubing, or drill pipe to a predetermined point in the well (Fig. 1). The slurry is formed by mixing water with portland cement or with cement blended with other materials. While this procedure is used to control gas-oil and water-oil ratios and for various types of liner jobs and remedial work, the most common purpose of cementing the casing is to exclude water. This is accomplished by forcing cement slurry into the annular space between the casing and the wall of the hole, allowing the cement to set and form a permanent barrier to the movement of undesired water.[3]

After having indications of oil or gas in probable commercial quantities, running and cementing casing is usually the next logical step. The drillstem test is commonly used to establish possibilities of economic production from sand and other types of producing formations. This method has been of immeasurable value to the oil industry. Much money has been saved by use of the drillstem test which permits the operator to test the possibility of producing horizons before running and cementing a string of casing.

Common practice in the industry is to set the casing at or near the bottom and to perforate the casing for expected production from information received from the drillstem test, core data, and electric log. In some instances the cas-

This article is one of a series of Modern Well Completions based on lectures given by industry authorities before a Petroleum Engineering Seminar course, PE-270, at The University of Texas, Austin.

The Most Efficient, High Pressure Valve Ever Made

W-K-M BALANCED STEM GATE VALVE

The W-K-M Balanced Stem Gate Valve, built to control well pressures up to 20,000 psi, uses the unique and proved parallel-expanding gate principle. A balancing stem permits easy spin-open, spin-shut operation. Turning the handwheel exerts tremendous sealing force at both upstream and downstream seats with positive mechanical sealing in both open and closed positions. Superior performance on highest-pressure wells has made W-K-M Gate Valves the standard of excellence the world around. Futhermore, as added proof, this valve successfully completed "tests more severe than ever attempted on similar equipment" by an independent laboratory. For full information send for bulletin WP 1157 and a copy of "The Crookston Report." ... P. O. Box 2117, Houston 1, Texas.

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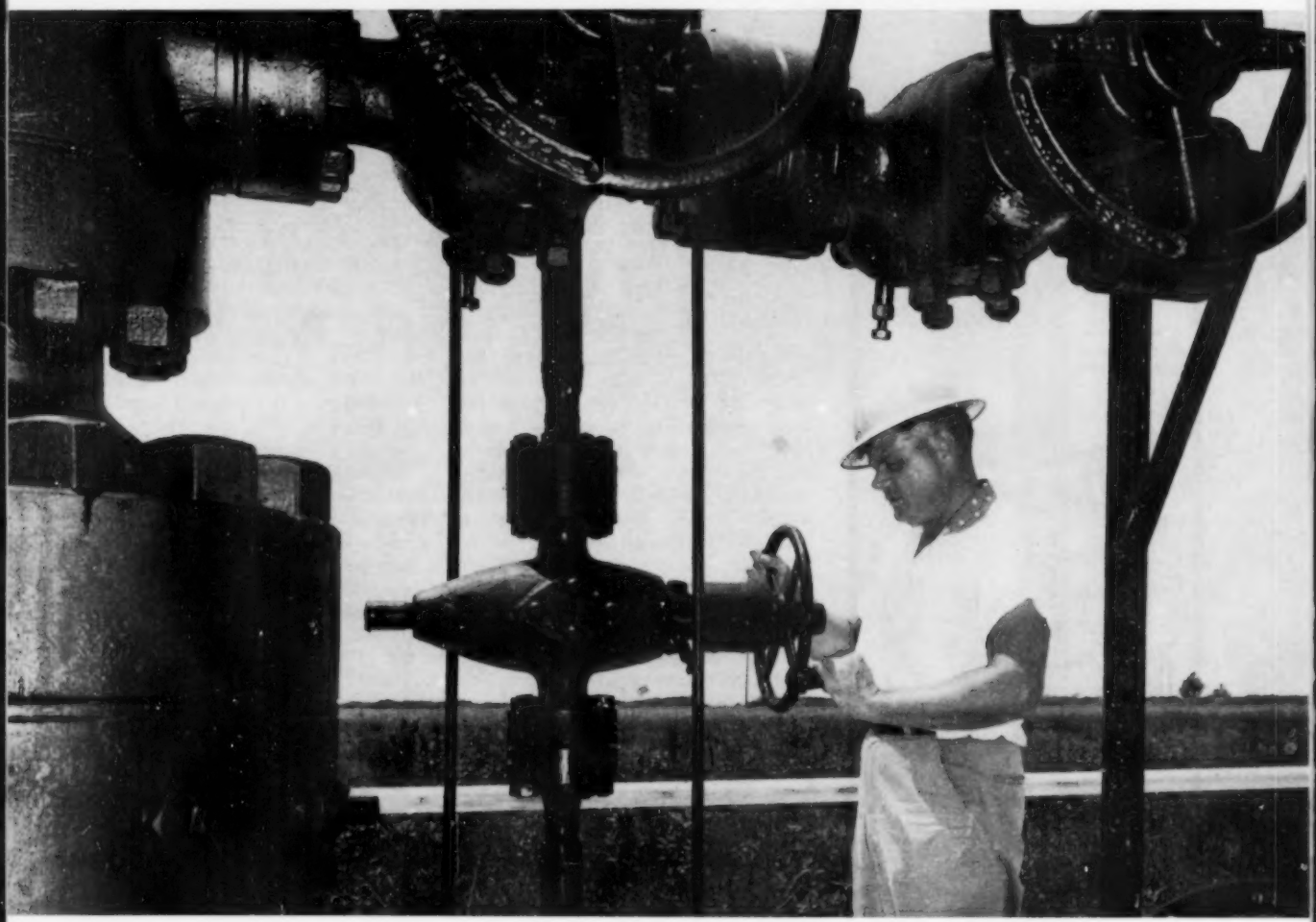

W-K-M DIVISION

ACF INDUSTRIES

ing is suspended and cemented above the producing formation and the well is produced from open hole. This is called "open hole completion." The final casing string is referred to as the "flow string" or "oil string." The field terms "long string," "production string," and, in some areas, the "water string," are used. The term "casing string" is defined as the total footage of casing run in the well at one time.

Principal Casing Strings

Conductor casing or pipe string (as the name implies) is used to conduct drilling fluid while drilling surface hole.

Surface casing is set to protect fresh water zones and to guard against possible cave-in of the surface formations and to provide for initial drilling control.

Intermediate or protection string is set inside the surface pipe to protect the hole. One or more such strings of pipe may be set.

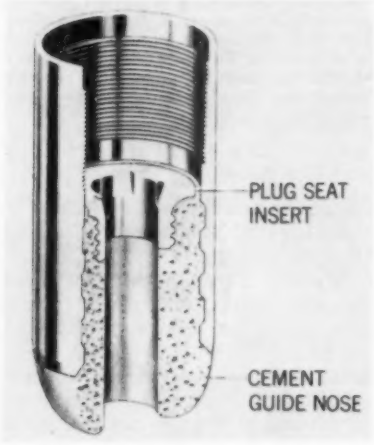

FIG. 2. Cement guide shoe serves to guide the casing to be cemented to its proper location and provides a seat for cementing plugs.

Oil strings are set to test well production and to complete the well as a producer.

During the producing life of a well the casing continues to keep the hole open and helps prevent entry of water. It confines the gas and oil, preventing them from passing into the other sands and conducting them to the surface. The casing can perform these duties only when it is cemented in the hole. By this method a tight seal is formed between the casing and the wall of the hole.

Cementing helps to accomplish the following: (1) bonds casing to formation; (2) protects oil-producing zones; (3) seals against contamination of fresh water zones that may be used for domestic supply; protects other formation strata such as coal, potash, etc.; (4) helps prevent blow-outs from high pressure gas zones behind the casing; (5) protects casing from excluded corrosive formation waters and lowers electrolytic currents; (6) seals off lost circulation zones or other troublesome formations in order to drill ahead; and (7) protects surface and protection strings while drilling additional hole.

Planning a Cement Job

Since selection of hole sizes and the casing program are usually determined before drilling is started, plans for cementing the oil string may also be made by the well owner before drilling begins.[4] Some factors which affect the cement job are:

Mud qualities. Care should be taken in conditioning mud. This can be a valuable aid in running casing and cementing the well.[5]

Selection and placement of special tools.

Running casing. The manner in which casing is run (including selection and location of surface connections) is of great importance during the cement job.

Amount and type of material. Varying well conditions make this a very important matter.

Mixing units. A sufficient number and proper type of mixing units, accessory equipment, plugs, and techniques are necessary to provide the best possible cementing job.

After these factors have been considered and the job has been planned, qualified and experienced personnel are needed to supervise and perform the job. Full cooperation of personnel representing the well owner and the service company will then make it possible to plan and successfully execute a much more efficient job.

Floating Equipment and Accessories

Attached to the casing are necessary devices such as floating equipment, centralizers, and wall cleaners. This equipment is assembled at the surface.

Floating equipment normally consists of a guide shoe and float collar attached to the bottom of the casing (Fig. 2 and 3). Sometimes two float collars and various combinations of float shoes and collars are run. The guide shoe is a round-nose device placed on bottom of the casing to guide the pipe as it is lowered into the hole. The float collar is placed from one to three joints above the bottom of the pipe to act as a back pressure valve and to reduce the weight of the casing on the derrick as it is placed in the

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well. Various designs are available but all are essentially back pressure valves that allow fluid to be pumped downward through the casing but do not permit fluid movement in the reverse direction. It also helps prevent the back-flow of mud or cement into the casing and acts as a stop for the plugs that are used to separate the cement and other fluids inside the casing during the cement job.[6]

A modified form of floating equipment permits casing to fill up as it enters the hole; but a back pressure valve or float valve can be brought into action by circulating drilling fluid through the casing or by various other methods. Circulation of fluid trips a mechanism at any chosen point after which the valve functions in the same manner as in other types of floating equipment. This type of mechanism is generally referred to as automatic fill-up equipment.

Casing centralizers are used to position pipe in the hole to aid in uniformly filling the annular space around the casing with cement. Considerable work has been done to gather data on the proper placing of centralizers and the number of centralizers necessary for various casing loads, depending upon hole size, casing size, and hole deviation.

Wall scratchers or cleaners are of various types and designs but all are used to improve the bonding properties of the cement to the formation by removing drilling mud filter cake from the bore of the hole. The two common types of cleaning devices are classified according to the method by which they are operated; one is activated by reciprocal motion of the pipe, and the other operates when the pipe is rotated.[7]

TYPES OF CEMENTING JOBS

There are many different types of cementing jobs and variations thereof, but all can be included under one of four general classifications: (A) cementing through pipe and casing; (B) cementing through drill pipe; (C) cementing through tubing; and (D) combination jobs.[8]

Cementing Through Pipe and Casing

Conductor, surface, and protection strings are usually cemented using the single-stage method. This method is also commonly used on the production string. Single-stage cementing is accomplished by placing one batch of cement through the casing shoe with various types of top and bottom plugs. Different types of heads such as single and double plug containers for continuous cementing procedures are available as well as special adaptations for rotating or reciprocating casing.[9]

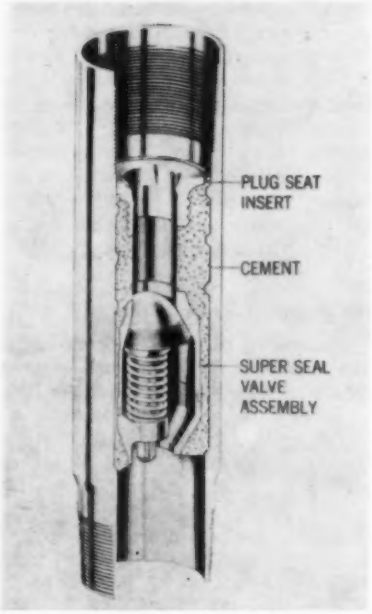

FIG. 3. A float collar is basically a back pressure valve that allows fluid to be pumped downward through the casing but does not permit fluid movement in the reverse direction. This helps prevent the back flow of mud or cement into the casing and also acts as a stop for the plugs that are used to separate cement and other fluids inside the casing during the cement job.

Multiple stage cementing uses the two-stage method, making it possible to do a cement job at the bottom through the casing shoe with the second cement batch being placed through the two-stage tool at any predetermined point in the casing. This job can be done as a continuous operation or it is possible to do the bottom job, open the tool and circulate before cementing through the two-stage tool. After the cement job has been completed on the two-stage tool, a special plug closes the outlet ports by operating a built-in sleeve in the tool.

Some of the advantages of two-stage cementing are: (1) full depth cementing; (2) cementing off formations at any point; (3) reducing pump pressure; (4) minimizing loss of cement slurry to thieving formation by lessening the hydrostatic head.

By special adaptation, multiple-stage cementing can be extended to three stages. Using this arrangement, it is possible to pump the first stage through the casing shoe and the two subsequent stages at predetermined points by placing two multiple-stage cementers — a two-stage and a three-stage tool — in the casing. The first two stages are run as a continuous operation. A bomb-

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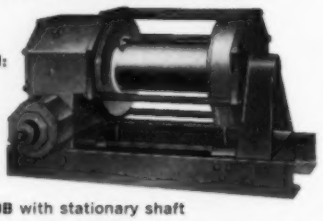

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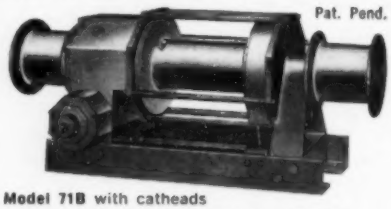

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type plug is then used to open the three-stage tool to run the third stage.

It is also possible to pump the first stage through the casing shoe, then open the first tool, circulate, allow the cement to set, and then pump the second stage through the first tool. The second tool is then opened, cement is allowed to set, and the third stage is pumped through the second tool. This arrangement requires special opening and closing plugs and tool sleeves, but it has been used successfully in the field to solve many special field problems.[10]

Liner jobs are performed using a special tool on the end of the pipe. In most cases liners are set from the bottom of the hole and extend back into the casing string above. Size of the liners varies according to the size of the casing string with which it is to be run. In some cases, more than one liner is run in a well, due to deepening operations which were not considered in the original casing program or in exploratory holes where it is not preferred to set a complete string of pipe to the surface. Several liner tools are available which can be used in various types of oil well cementing.[11]

Bull head squeeze job in casing or pipe refers to the practice of using a plug contained in the casing and pumping cement straight down the casing with no tubing in the hole. The plug is released and is usually followed with a measuring line. This job is usually used on comparatively shallow wells, the amount of pressure depending on the casing. In the event all the cement is not pumped away, the excess cement and plug are drilled out. In some areas, this type job is referred to as a "casing squeeze."

The term "casing squeeze job" is also used in a very broad sense to refer to other casing cement jobs using various combinations of cement slurries.

Cementing Through Drill Pipe

When a cementing job is performed through drill pipe, pressures are limited to the bursting pressure of the drill pipe and the bursting and collapse pressure of the casing. This type of operation is used to perform open-hole plug-back jobs for the purpose of: (1) placing lost circulation materials; (2) setting a plug prior to abandoning the hole; (3) setting a plug prior to placing a whipstock for directional drilling.

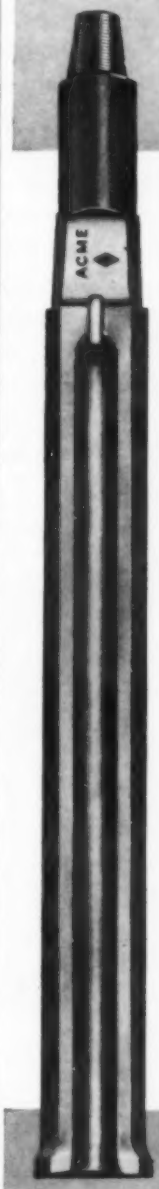
Straight plug-back jobs in casing are used for various purposes: (1) to abandon perforated sections of producing zones in order to re-perforate and produce a different interval; (2) to plug off the bottom of the casing; (3) to shut off water; and (4) to cut window for whipstock operations.

A bradenhead job is a special squeeze job in which the tubing or drill pipe is packed off at the surface without any downhole tools. Pressure is above that necessary to place and wash out any excess cement. Cement slurry is forced into and against the formation, with pressure limited by the strength of the casing and its bradenhead or casing head. This technique is used in permanent-type well completion remedial work. Low fluid loss material is placed through perforations and the excess cement reversed in order to eliminate drilling out.

Cementing Through Tubing

If, in the case of squeeze cementing, the job is to be done at extremely high pressures, tubing or 2⅞ in. or 3½ in. drill pipe is generally used. The pressure is applied to the tubing down to the tool which is packed off inside the casing. Tools of various types — drillable, retrievable, and a special liner tool which has packers that create a pressure seal or barrier between the tubing and casing — are made for this purpose.

The term "squeeze job" is usually



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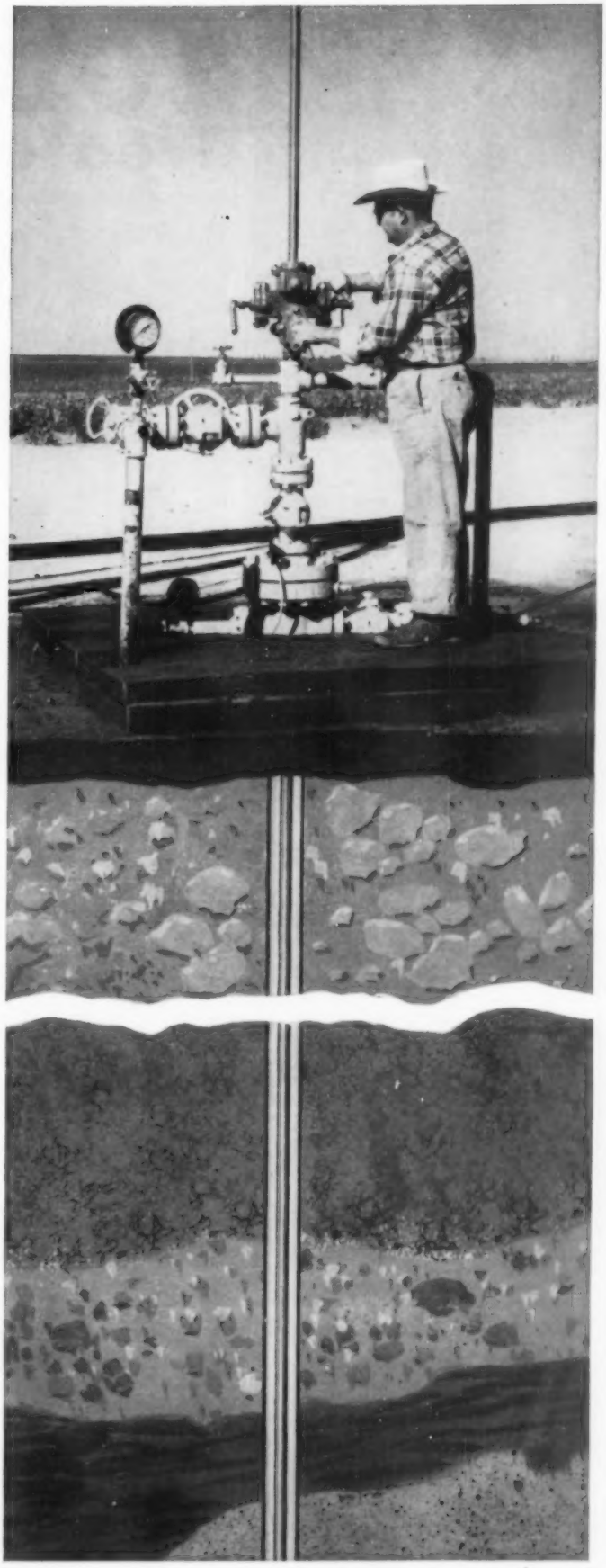

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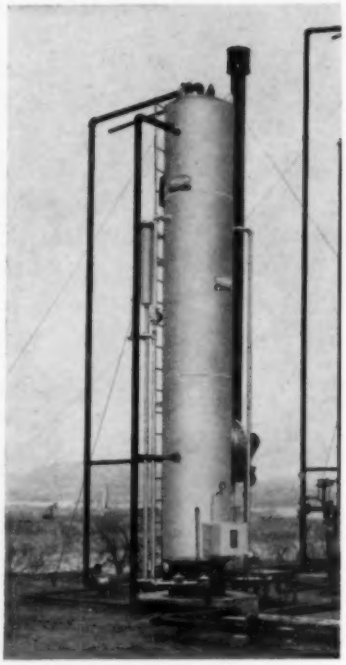

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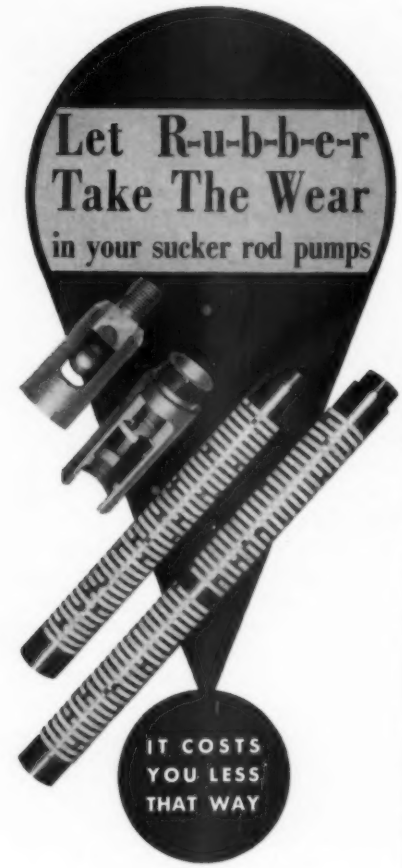
applied to any job involving pressures in excess of that necessary to place cement and wash out the excess. In other words, in the process of squeeze cementing, pressure is applied to pump the cement away, into or against the formation for controlling gas-oil or water-oil ratios, or other remedial work. The slurry is pumped through perforations or into open-hole formations to accomplish these results.

Experience has proved that it is desirable to break down the resistance of a formation to passage of cement slurry by pumping water or acid into the formation ahead of the cement slurry. It has been found that the break-down pressure required to start water into a formation in many instances is considerably in excess of the fluid pressure existing in the formation. As soon as fluid enters the formation, pressure required to continue injection usually drops noticably, and great quantities of additional fluid can be pumped in without increase in pressure. After a steady flow of water into the formation has been established, and the injection pressure has reached a minimum, the water is followed by cement.

Squeeze cementing as now practiced is a refinement of old plug-back methods used earlier to accomplish the same results. In the earlier process of pressure cementing, pressures were applied to the light casing string and thus were limited to the maximum internal pressure that the casing would withstand. By present methods the limit of pressure is determined mainly by the bursting strength of the drill pipe or tubing and by the maximum working pressure of the pumps. Development of the cement retainer to eliminate high pressure against the casing and improvement in high pressure equipment are the two main factors that have contributed to the success of modern squeeze cementing.

The term "block squeeze" or "protection squeeze" is applied to tubing squeeze jobs using a tool, either drillable or removable, and squeezing through perforations above and below the formation to be produced before the final perforating job for producing the well is performed. In other words, the casing is perforated, squeezed, and perforated again at the point at which the well is to be completed. This method is used to improve the bond of the cement between the casing and formation and to block or protect the producing formation from fluids above and below in high gas-oil ratios or where



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high pressure water is in contact with the producing formation.

The term "scabbing" is applied to special repair work done primarily in California. Scabbing may be done either by placing cement against the face of the sand, or by using a sleeve on the inside of the liner. Sealing perforated intervals is commonly referred to as scabbing.[12]

Another California term is "CP." This is actually a broad term covering any cementing through ports or perforations, usually excluding a normal squeeze job. The most accepted use of the term refers to the use of a port collar in the casing string in such a manner that cement is diverted through the pipe at one particular point back up the annulus.

On a liner job using a bradenhead, a wash pipe can be attached below the setting tool. After cement has been pumped up around liner, the casing is closed and cement is pumped into the formation. Pressure is released and the tool is backed off; and then cement washed out of the liner and out of the casing. It is also possible to use a setting tool which attaches to the bottom of the liner. On this type of arrangement, it is possible to wash out to the bottom of the liner, wash the excess cement out of the liner and casing, and perform a bradenhead squeeze.

Another type of liner squeeze job uses a tool to keep pressure off the casing. This tool uses a wash pipe which extends to the bottom of the liner. After cement has been pumped up around the bottom of the liner, the tool is backed off from the top of the liner. Then, by letting the weight of the drill pipe down on the tool, the packer is collapsed between the liner and the casing and held down by hold-down slips.

On the wash pipe in the liner there is a second packer which allows the operator to pump cement down through the drill pipe and out through the anchor shoe without applying pressure on the casing. Pressure is held on the formation by the packer between the liner and the production string by the back pressure valve in the bottom of the anchor shoe. Pressure in the drill pipe is then released and the packer on the inside of the liner is pulled out above the top of the liner and the cement is washed out of the casing and liner.

Other Cementing Jobs

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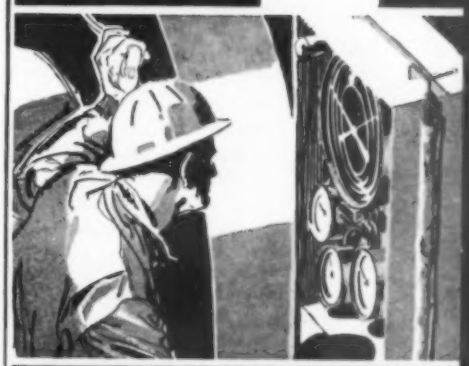

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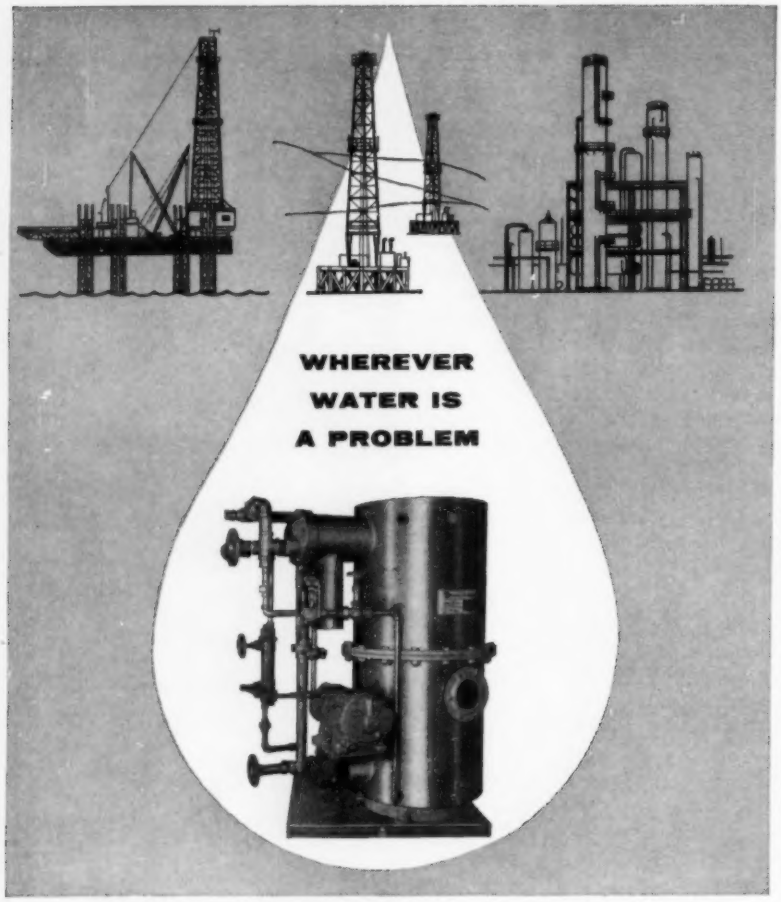

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casings or between casing and hole is used to bring the top of the cement to the surface. In some cases this method is used for remedial work.

Cementing the annulus between strings through a casing head connection is sometimes necessary to repair casing or to cement the strings together due to high pressure gas sands being charged from surrounding wells.

Permanent-type well completions require special cementing operations. Simplified equipment and techniques have been developed to permit cementing a completion interval in a well and re-completing higher, lower, or at the same depth in such a manner as to eliminate the need for a conventional drilling or workover rig. This technique involves the use of a small-diameter, light-weight, tubing extension run on a wireline and set in a landing nipple previously installed in the tubing string. Low squeeze pressure and small cement volumes, with their attendant cost reduction, are successfully used when wells are completed and reworked with salt water or other penetrating fluids.[12]

Dump bailer equipment is utilized to perform many different types of jobs and to place many different types of materials, such as nitro-glycerin shot tamps, water shut-off, plug below damaged pipe, plug to set liners, plug back jobs, and caving conditions in cable tool hole. These jobs usually use the knife-type bailer bottom. Special bailers for dumping gravel using a glass disc and types of bailer bottoms are in use. The dump bailer is also used to dump caustic in removing magnesium windows.

Stuffing boxes are used on the bailer line in order to apply pressure on material that has been placed with a bailer and have proved to be an advantage in overcoming field problems. Dump bailers that can operate off a measuring line or electric line in 2, 2½ and 3 in. tubing are in field use. By using the measuring-line bailer in these different tubing sizes and using a stuffing box for the measuring line, work has been done with this equipment in placing material without killing the well. Special bridging baskets and casing plugs that operate off the measuring line are available for dump bailer work.

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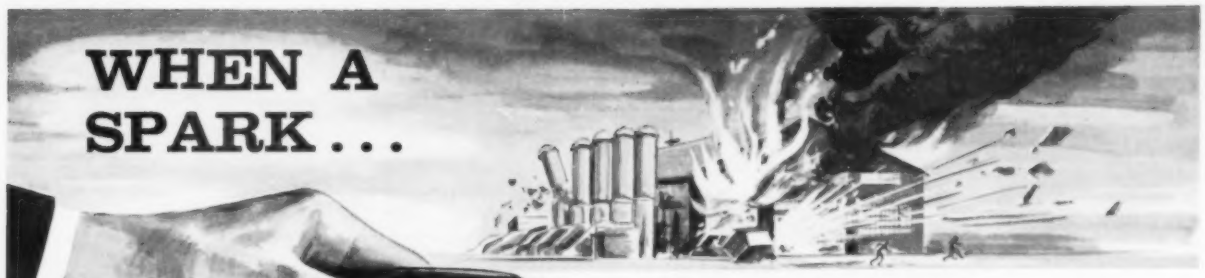

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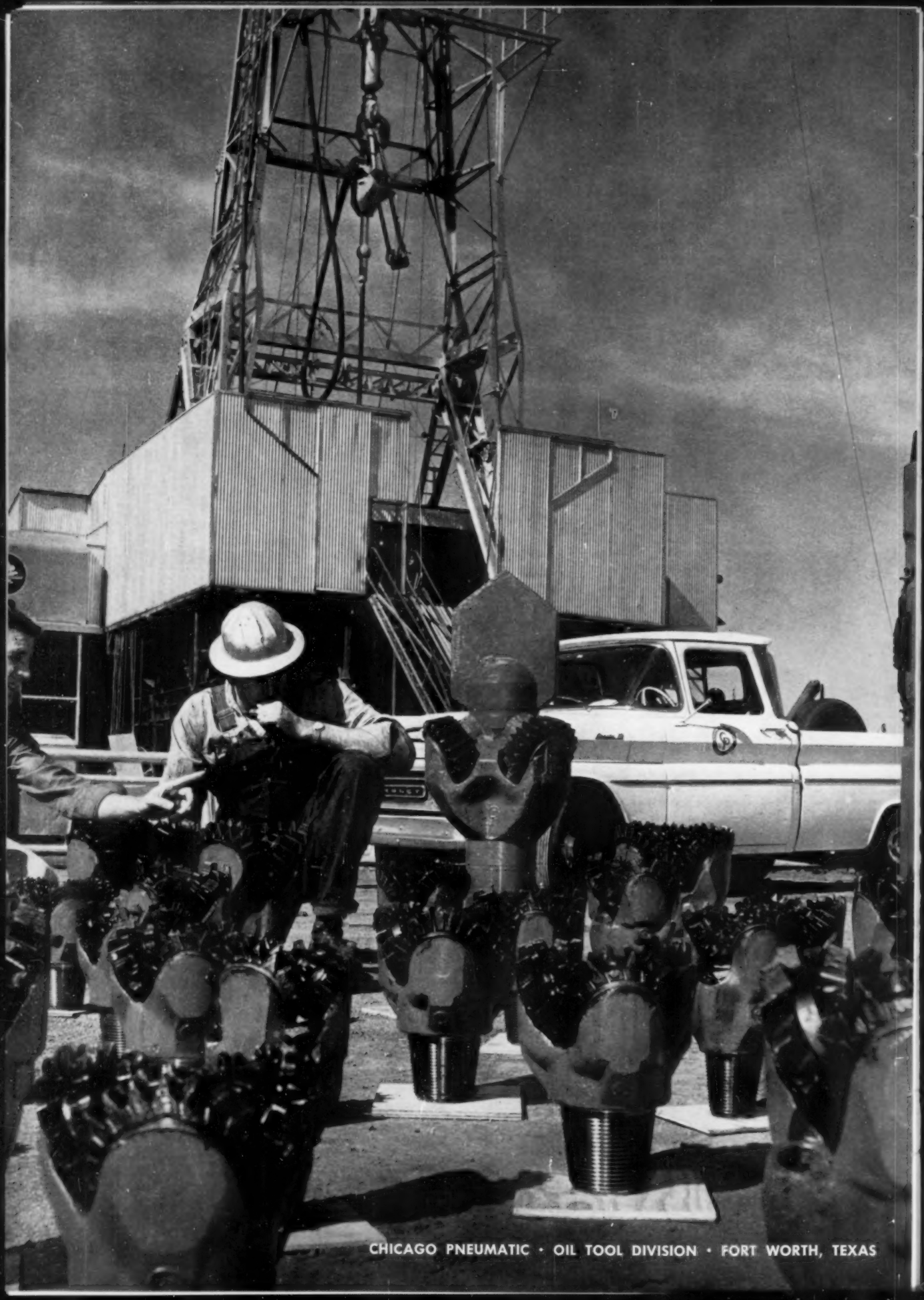

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cementing, displacement plug cementing, set-cement removal, sand control, acidizing, and combinations. The main part of the work with concentric tubing has been done on the Louisiana Delta. Although it is a relatively new idea, it has been field tested and accepted.[14]

In multiple tubingless completions, two or more strings of small-diameter pipe (usually 2⅞ in. tubing) hang side by side, cemented in the open hole. There is no single large-diameter oil string as in conventional completions. In effect, each of the small-diameter strings is a separate well. While all strings are suspended from a common casing head, there is no down-hole flow path from one to another. Therefore, it is not possible to pump down one string and circulate back up another. This method does away with the oil string and tubing packers of a conventional multiple completion.[15]

A relatively new method has been developed for repairing holes or weak spots in casing without removing the pipe from the well. The method utilizes an inflatable rubber mandrel for forcing plastic-impregnated glass fabric against the inside of the pipe. Excess plastic is forced out of the hole, forming a seal both inside and outside the casing. Pressure is maintained while the plastic hardens. The patch, capable of withstanding differential pressures of over 5000 psi reduces internal diameter of the pipe by only three-tenths of an inch.[16]

The wire-line squeeze tool, a radical departure from conventional squeeze-cementing equipment, consists basically of a high-pressure gas gun, with an aluminum retainer disc bottom. The gas gun, loaded with a rocket propellant, is attached to the firing head of an electrical line and the necessary small amount of prepared cement slurry poured in the cement container. The tool is run in the well and stopped just above the top of the perforations or the desired top of the plug. When fired, the powder burns and generates a gas which first sets the anchor and then expands and sets the packing element against the casing. Continued pressure build-up caused by the burning propellant ruptures the aluminum retainer and disc and forces cement into the perforations or formation. This tool is available for 5½ in. and 7 in. OD casing.[17,18,19]

Conclusion

Primary cementing is referred to as the original cementing operation which is performed immediately after the pipe or casing has been run into the hole.

Secondary cementing is any and all remedial or corrective cementing after the initial completion.

There are many combinations of jobs that have been mentioned in this discussion. In individual fields or sections of the oil country, terminology still reflects local names. The combination jobs listed are the main jobs spoken of in the oil fields, but in special problems many unique combinations might be considered.

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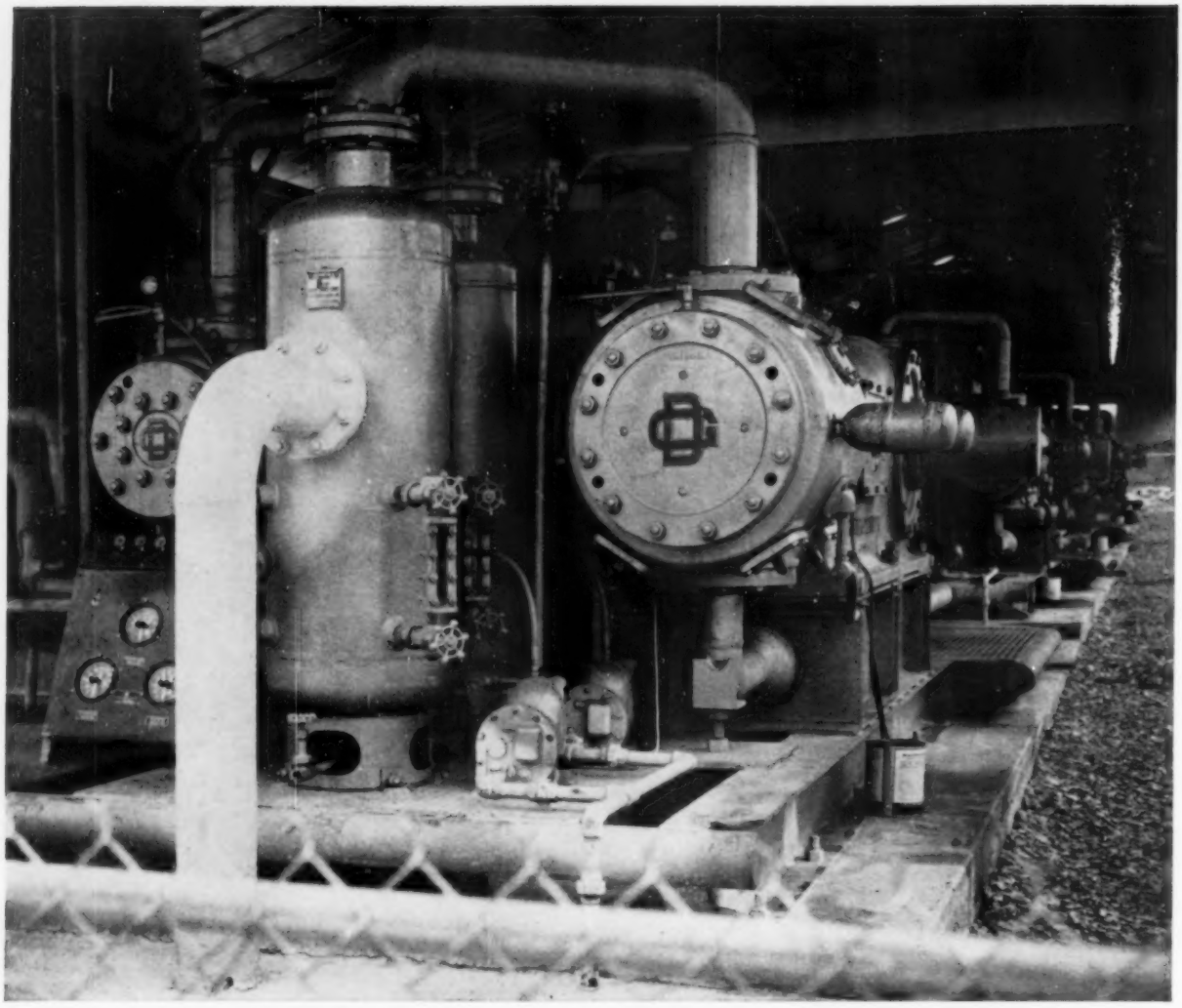
To Be Continued

The second part of this article will appear in next month's issue of The Petroleum Engineer.



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Larkin Heads Suppliers

W. H. "Bill" Larkin, (right) president of Larkin Packer Co., division of the Koehring Co., Waxahachie, Tex., was elected president of the Petroleum Equipment Suppliers Association at its recent annual meeting at White Sulphur Springs, West Virginia. Larkin succeeds Elliott Johnson, vice president of Schlumberger Well Surveying Corp., Houston, Tex., elected a director-at-large.

New PESA vice president is W. J. McWilliams, (left) president of Republic Supply Co., of Oklahoma City, Okla. H. R. "Bob" Safford was reelected executive vice president.

Directors-at-large are: Frederick F. Murray, Oil Well Supply Div., Dallas; Ted Sutter, Baker Oil Tools, Inc., Los Angeles; F. W. Mayer, Continental-Emsco Co., Dallas; M. B. Jones, The S. M. Jones Co., Div. of Buffalo-Eclipse Div., Toledo, Ohio; D. D. Bovaird, The Bovaird Supply Co., Tulsa, Okla.; M. E. Montrose, Hughes Tool Co., Houston; Rainey Elliott, Jones & Laughlin Supply Div., Tulsa; Grover Kilgore, Halliburton Company, Duncan, Okla.; Wallace D. Wilson, Wilson Supply Co., Houston; and Elliott A. Johnson.

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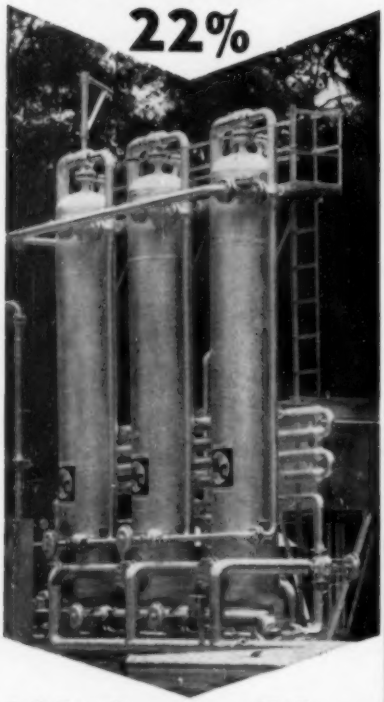

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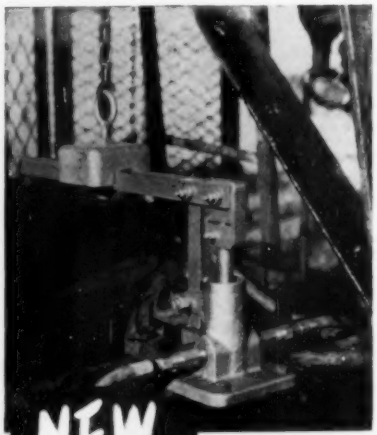

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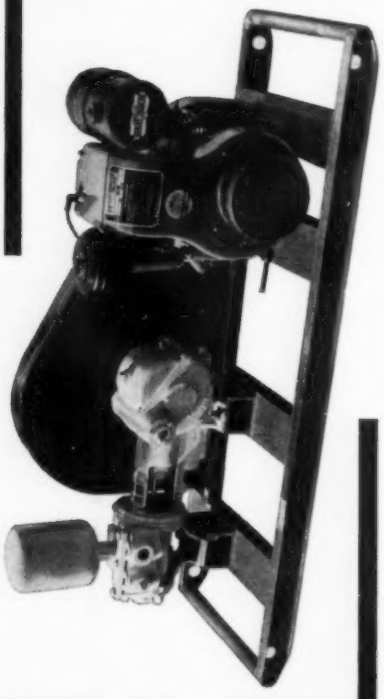

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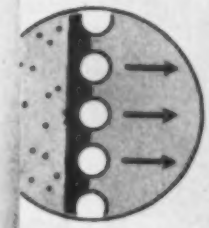
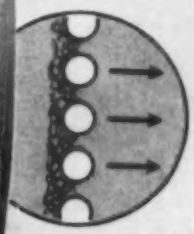
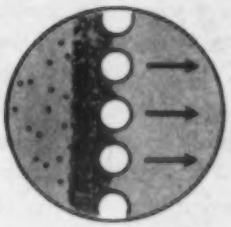


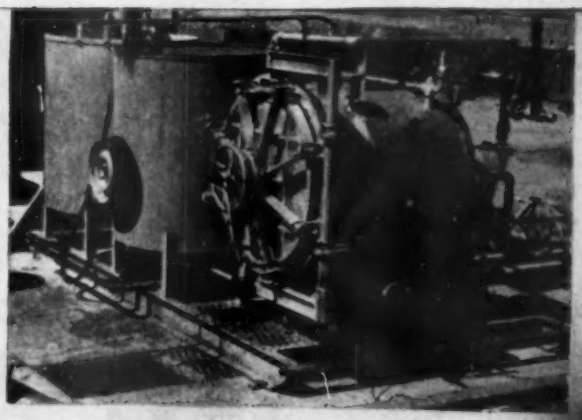
WITHOUT CELITE, fine suspended solids form a clogging seal over filter openings.



WITH CELITE, a porous cake with microscopic channels becomes the real filter surface.



DURING FILTRATION, continuous bodyfeed of Celite builds up fresh filter surfaces, greatly extending cycle life.



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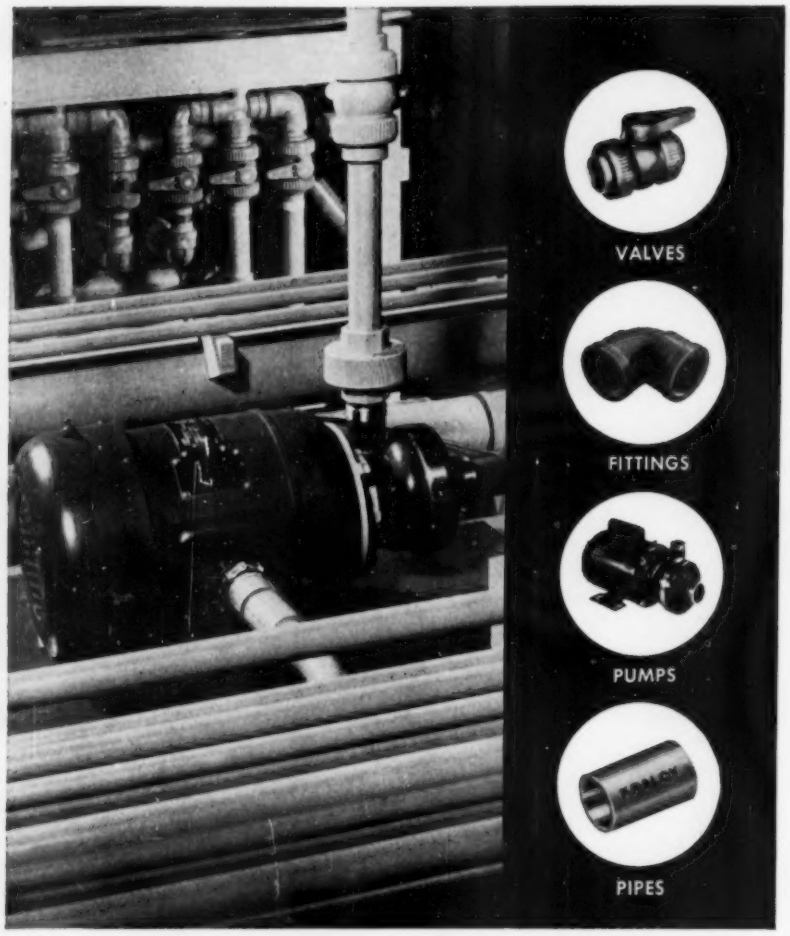

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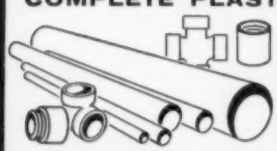

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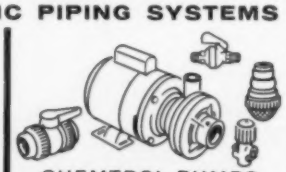

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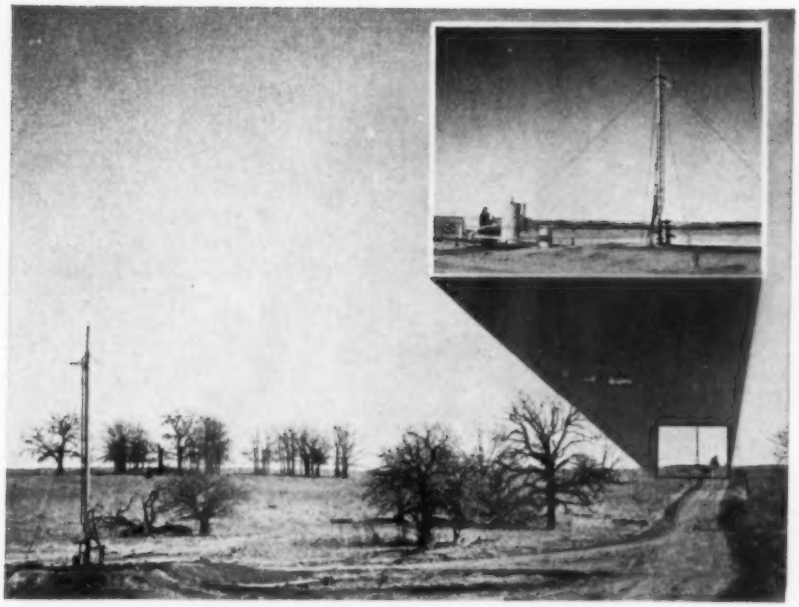
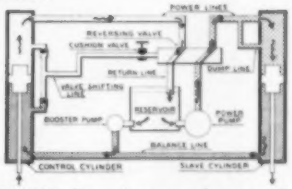


OKLAHOMA offset installation of EOT-Johnston Rod-Counterbalanced pumping units.

How the EOT-Johnston unit operates:



HYDRAULIC flow diagram showing Control Piston on upstroke.

In the illustration above the piston appears to be lifting only the fluid weight on the net plunger area with the rod weights cancelling each other. However, the buoyancy in the downstroke well will subtract from the counterbalancing effect of the rods so that the upstroke load is actually the fluid weight on gross plunger area. This is in contrast to a single counterbalanced unit where the effective load is one-half the gross plunger load, but the EOT-Johnston unit is pumping **two** wells.

Hydraulic units cut capital outlay 50%

- **EOT-Johnston Rod-Counterbalanced units save more than $13,000 on 9500 ft. dual-zone offset wells in Oklahoma.**

An Oklahoma oil operator selected the hydraulic method offered by Engineered Oil Tools, Inc. to pump his offset wells, effecting a saving of more than $13,000 on two EOT-Johnston Rod-Counter balanced hydraulic pumping units over an alternate proposal. These pumping wells are located near Healdton, Oklahoma.

Operating conditions: This installation, shown in the photograph, involves two wells on 40 acre spacing. Each well has a dual-zone pump, making a total of **four** zones pumped with the two rod strings. The zones are at 9000 and 9500 ft. The rated polish rod load is 29,000 lbs. and the units are operating at three strokes per minute on a 16-ft. stroke, producing at a displacement rate of about 115 barrels per day from each well. The connecting pipe line is 3½" O.D. by .125" wall electric resistance welded, X-42 grade. Total installed price of units (pipe, engine, hydraulic oil and all surface equipment except wellhead) was approximately $12,800 for the two wells.

Alternate equipment considered was beam units having a 100-inch stroke, 27,000 lb. beam rating, 320,-000 in.-lb. gear box, operating at six strokes per minute. The installed price of this equipment was approximately $13,250 **each** as compared to the $12,800 for **both** wells equipped with the EOT-Johnston units. This Oklahoma operator is pumping his two wells for the price of one — a substantial saving on capital outlay.

Simplicity of design: The EOT-Johnston unit was engineered to meet field operations and maintenance requirements. There is no complicated starting procedure, either. It is only necessary to start the pumping unit's power package. The unit automatically pre-charges itself, begins operation, and once in operation times itself and keeps the two cylinder units in phase automatically. Actually the operation and maintenance of the EOT-Johnston Rod-Counterbalanced hydraulic pumping unit is no more complicated than that of an automobile with an automatic transmission. Should the unit require more than routine field servicing, Engineered Oil Tools, Inc. has a service staff and spare parts available in all major operating areas.

Maintenance consists of checking the oil level and oil filter and tightening the packing occasionally.

The Balance Pressure is that required to lift rod weight plus net fluid weight in the upstroke well, plus acceleration load. The Balance System is not a dynamic circuit, as the hydraulic fluid simply "washes" back and forth, in a U-tube effect.

The speed of shifting is governed by the setting of the Cushion Valve, which restricts the flow into Reversing Valve. This allows a gradual deceleration of the Control Piston, and Slave Piston also, as the latter is governed entirely by the action of Control Piston.

Investigate the economics of pumping your wells with an EOT-Johnston Rod-Counterbalanced hydraulic pumping unit. Pump dual completions . . . offset wells up to 160 acre spacing with one power unit . . . and save up to 50% over other rod pumping methods.

EOT has a new fact-filled catalog on the Rod-Counterbalanced pumping unit. If you would like more information to save your company production dollars, write or call: Sales Department, Engineered Oil Tools, Inc., 1710 Burnett, Houston, Texas. Complete information will be sent you by return mail.

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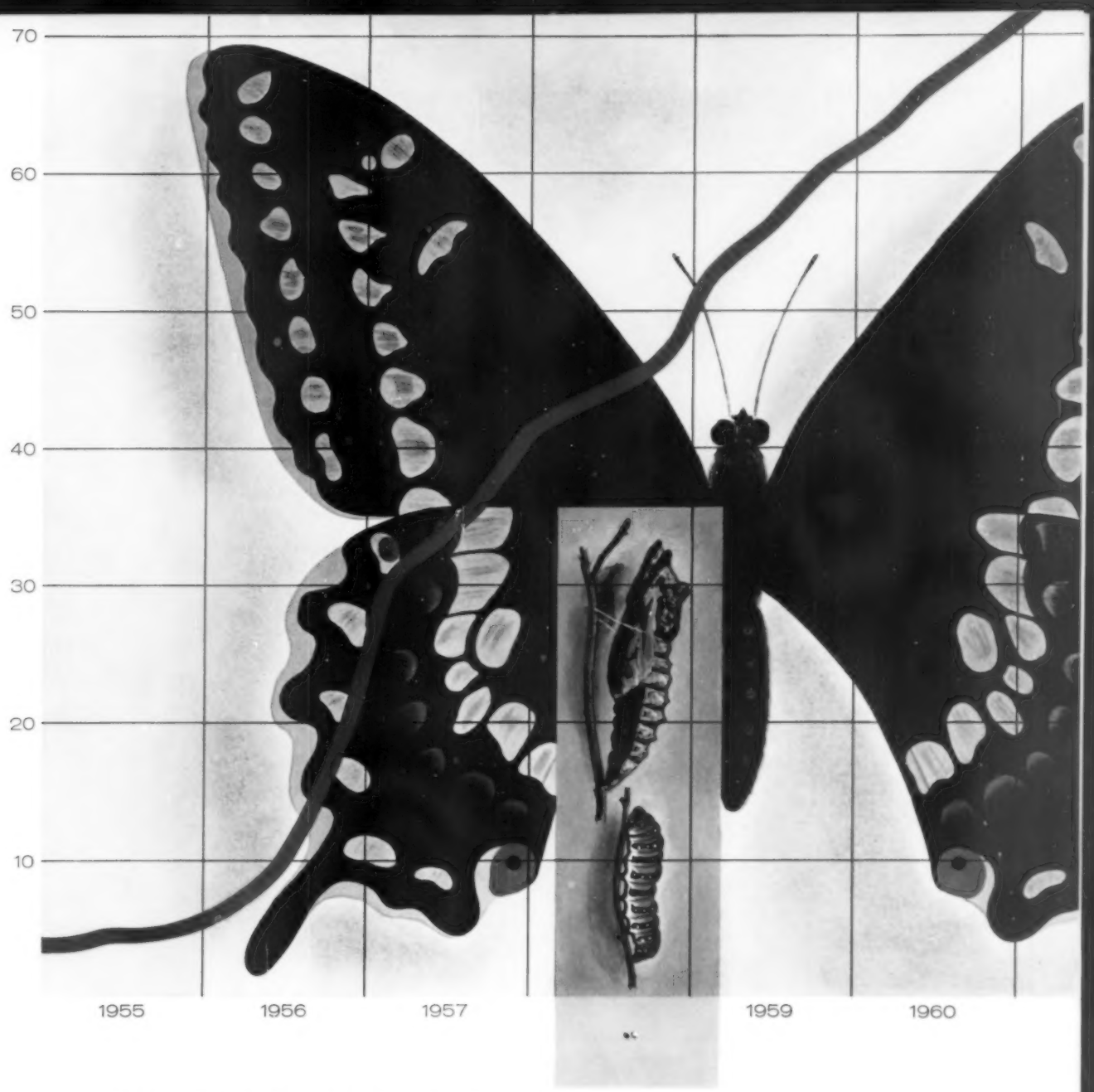
FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD



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GROWTH!

Schlumberger is proud of the petroleum industry's acceptance of Induction-Electrical Logging. This service was developed and introduced by Schlumberger only five years ago. The impressive growth is a testimonial for this broadly applicable service.

Most operators have proved the two-fold superiority of the Induction-Electrical log . . . more reliable identification of oil and gas zones and more accurate evaluation of productivity.

With today's increased demand for greater efficiency, the industry has profited through the use of the Schlumberger Induction-Electrical Survey. It will do a better job for you, too.

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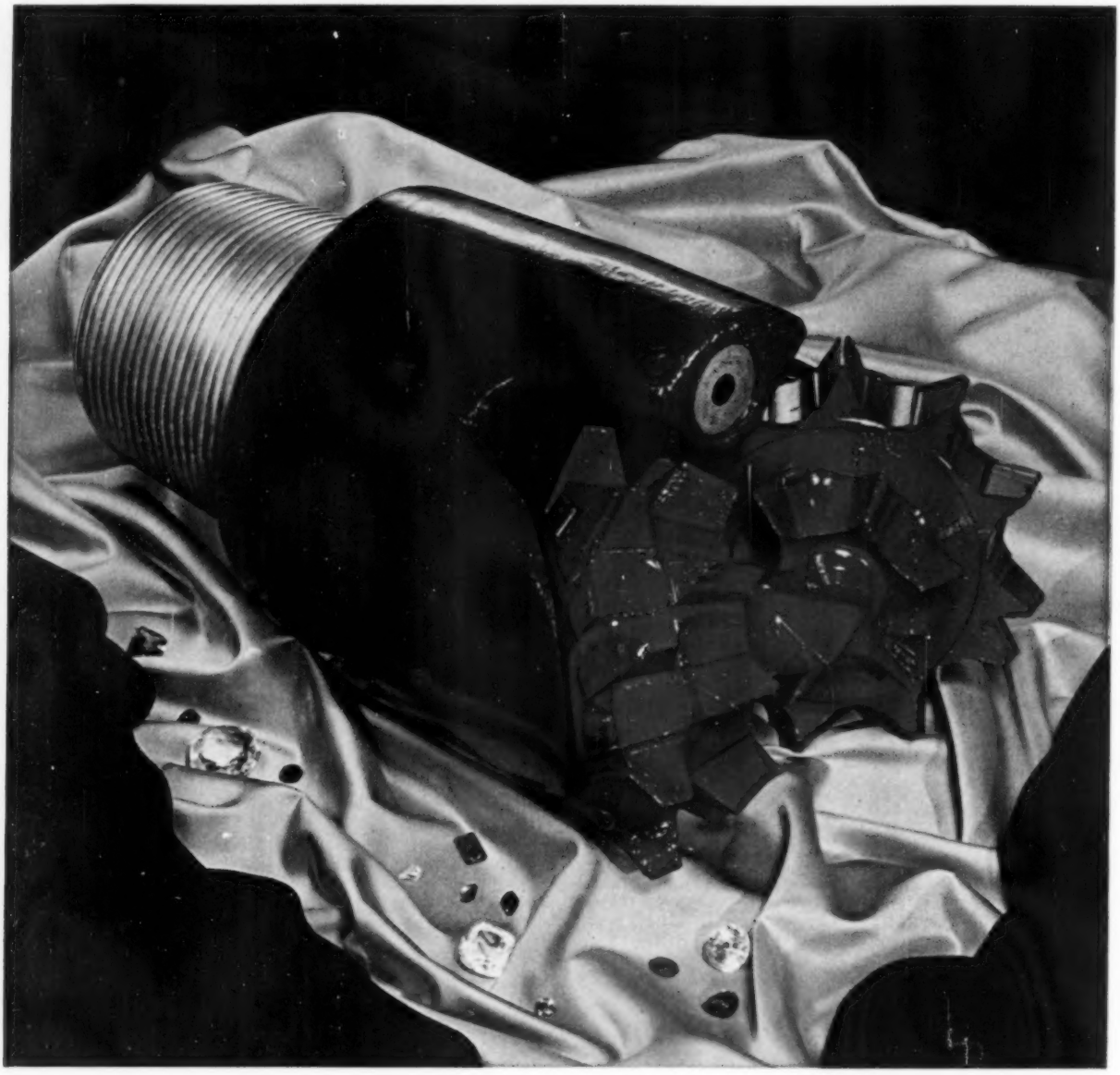
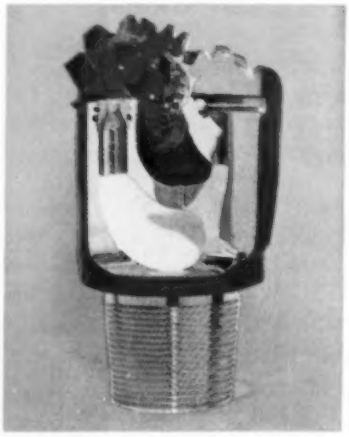
THE EYES OF THE OIL INDUSTRY



A SECURITY FIRST! New Extended Jet 2-Cutter Bit

Nothing drills like the new Security Extended Jet . . . because *there's not another bit like it!* This Security-First in 2-cutter bit design is setting new standards of superior performance. In formations of high drillability where added cleaning of bottom hole is vital, the new 2½" closer-to-bottom jet gives extra penetration speed. Less downtime and more accuracy are assured for straight hole and specialized directional drilling!

Call or write today for complete information and size availabilities on this revolutionary Security FIRST!



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Better Production Tools Through Research

OTIS Equipment NEWS

Volume III, Number 2 **Otis Engineering Corporation • Dallas** *Production Equipment and Services*

Otis 1¼" I. D. Gas Lift Valves Lift 370 BWPD From New Tubingless Completion Gas Well

LAKE CHARLES—A major Southern Louisiana producing company recently used Type C Otis Macaroni String Gas Lift Valves to unload water from a new tubingless completion to save several thousand dollars in swabbing costs. In excess of 18,000 barrels of water were lifted through the 1¼" I.D. tubing and Otis Gas Lift Valves in less than two months time. Following the unloading operation, the pipe was salvaged and the valves exchanged for a new set of a different size for use in one of the company's oil wells.

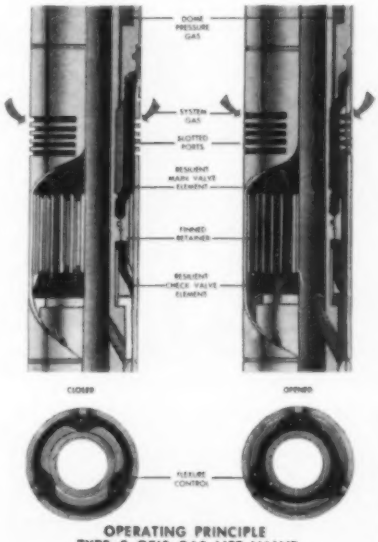
TYPE C OTIS GAS LIFT VALVE

Well conditions at the time the Otis Gas Lift Specialists made their recommendations were as follows: T.D. of the well was 7300 feet. 2⅞" tubing had been run and cemented to serve as a casing. Water encroaching from the down-side of the producing horizon was preventing production.

At the recommendation of Otis Gas Lift Specialists, the operator ran 7250 feet of 1¼" tubing with a packer on the bottom, and nine 1¼" Type C Otis Macaroni String Gas Lift Valves made up in the string. The lowest valve was located at 5900 feet. Using a 900 lb. supply gas system, an average of 370 barrels of water per day were lifted from a valve located at 4400 feet. The injection gas ratio was less than 300 cubic feet per barrel of water. The operator credited Otis Gas Lift Specialists with saving him swabbing costs of between $4,000 and $6,000.

Valve Design Features

Otis Macaroni String Gas Lift Valves provide the same outstanding design features to be found in the larger, standard size Type C Otis Gas Lift Valves. Available in sizes ranging from 1-13/32" to 3" I.D., Type C Valves have a full-opening bore, collar O.D. and tubing I.D., are concentric in design, have only two moving parts — no moving metal parts, no bellows to fatigue, no seat to cut out and no spread. The valve has one operating pressure — the set pressure of the valve.



OPERATING PRINCIPLE TYPE C OTIS GAS LIFT VALVE

Otis Gas Lift Valves are designed to provide the ultimate in lifting efficiency and capacity, and for use in continuous or intermittent lifting operations without modification. Type C Otis Gas Lift Valves with Pack-Off Assemblies are currently being used to convert wells to gas lift without pulling the tubing. This technique of converting a well to gas lift saved one producer as much as $60,000 in converting three readily accessible land wells.

Otis Gas Lift Specialists and Completion Specialists are interested in helping you complete and produce your wells in the most efficient way possible. Their experience — gained through years of solving difficult production problems encountered in all the major producing areas of the world — will prove invaluable to you. Use the knowledge of these men and spend your production dollars more economically and efficiently. For more information on Otis Gas Lift Valves, sizes and lifting capacities, contact your nearest Otis office or write Otis, Dept. E-2, P. O. Box 35206, Dallas 35, Texas. You'll find experienced Otis Gas Lift and Well Completion Specialists ready to help you . . anxious to serve you . . and with the widest variety of field proven production equipment and services available today.

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OTIS
Engineering OTIS Corporation
General Offices:
6812 Denton Drive • Dallas

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

New Literature

Oil Field Pipe

Two hard-backed, illustrated books provided by Mannesmann-Export cover manufacture of oil field pipe, its use in drilling operations, calculations and tables. Volume I, Mannesmann Pipe in Oil Field Service, 71 pages, describes process of manufacture—pipe materials, subsequent operations, testing and inspection. Volume II, Useful Information for Oil-Field Experts, 74 pages, covers most phases of calculating drill pipe and casing requirements. Tables give specifications on casing, tubing, drill pipe, and line pipe. Both volumes fit into bound case provided. *Mannesmann-Export GMBH.*

Circle number (1) on reply card.

Pumping Controllers

Bulletin GEA-7310, eight pages, describes General Electric's complete line of 220 and 440 volt oil well pumping controllers for outdoor operation of polyphase motors up to 100 hp. Special section describes controllers rated 220 and 440 to 762 volts, available for use with Tri-Clad 55 motors equipped with new Thermo-Tector system for inherent overload protection. *General Electric Company.*

Circle number (2) on reply card.

Packaged Compressors

A cut-away illustration in a six-page, three-color Clark Bros. Bulletin 191 shows features of their new Model TVM VeePac packaged compressors. These 2-cycle, turbocharged, gas-engine-driven compressors with V-type engines and horizontally-opposed compressor cylinders come in 10 or 12 cylinder models rated at 825 and 1000 bhp. Bulletin tabulates specifications and dimensions. *Clark Bros. Company.*

Circle number (3) on reply card.

Closed Rotation Gas Lift

Folder from Merla Tool describes closed-rotation gas lift systems in detail. It includes diagrams of several types of installations employing this method of gas lift in reservoirs without large gas wells. *Merla Tool Corporation.*

Circle number (4) on reply card.

Slim Hole Tubing

Four-page color brochure describes Jones and Laughlin's Slim Hole T and C Tubing. This specialty product designed for multiple completion wells comes in three grades, H-40, J-55, and N-80; and three sizes, 2 1/16-in., 2 3/8-in., and 2 7/8-in. OD. *Jones and Laughlin Steel Corporation.*

Circle number (5) on reply card.

Fracture Conductivity

Booklet gives 16 pages of technical data on fluid flow through fractures, partial monolayer propping of fractures, and laboratory data. This includes equipment used in tests, effect of formation hardness, actions against propping agents. It gives field applications shown by graphs. *Dowell Division.*

Circle number (6) on reply card.

Carbon Dioxide Storage

Bulletins illustrate and describe Cardox's bulk liquid carbon dioxide systems. First describes steel-housed storage units from 2, 4, 6, and 12 ½-ton capacity, the second 17 to 52-ton capacity units. All units have insulated pressure vessels. A bibliography offered lists articles on secondary recovery using carbon dioxide. *Oildox Services.*

Circle number (7) on reply card.

Sucker Rod Couplings

Nyloglide couplings for sucker rods and reciprocating pipe are illustrated and described in a four-page brochure. Jacket made from nylon reinforced with fiberglass and lubricated with molybdenum disulphide reduces friction and wear, manufacturer states. Couplings fit rod sizes from ½-in. to 1-in. *Liberty Manufacturing Company of Texas.*

Circle number (8) on reply card.

Power Slush Pump

National K-380 power slush pump specifications, features, and performance are given in a 12-page Bulletin No. 520. It presents this 380-input-hp pump, describing its design and provisions for performance and maintenance. *National Supply Company.*

Circle number (9) on reply card.

Setting Subsurface Tools

Data sheet shows how to selectively set subsurface locks and tools with Camco's Magnaset. Tool uses automatic release of self-contained energy and operates from a wire line. *Camco, Incorporated.*

Circle number (10) on reply card.

Planning Logging Program

Preferred Logging Program, Brochure No. PL-261, was issued by Lane-Wells Company to help logging users select right service for desired information. It lists all of firm's open hole and cased hole logs to show at a glance recommended log or combination for various hole conditions. Geographical subdivisions list major areas of oil activity in United States for easy reference. *Lane-Wells Company.*

Circle number (11) on reply card.

Gas-Processing Equipment

A 12-page picture brochure shows Maloney-Crawford's Gas Story through field installations of their gas processing equipment. It includes stabilizers, glycol units, dehydrator and adsorbers, heaters, regenerators, contactors, separation units, high pressure knockouts, flame arresters, scrubbers, and a packaged gasoline plant. *Maloney-Crawford Tank and Manufacturing Company.*

Circle number (12) on reply card.

Valve Actuator Bulletin

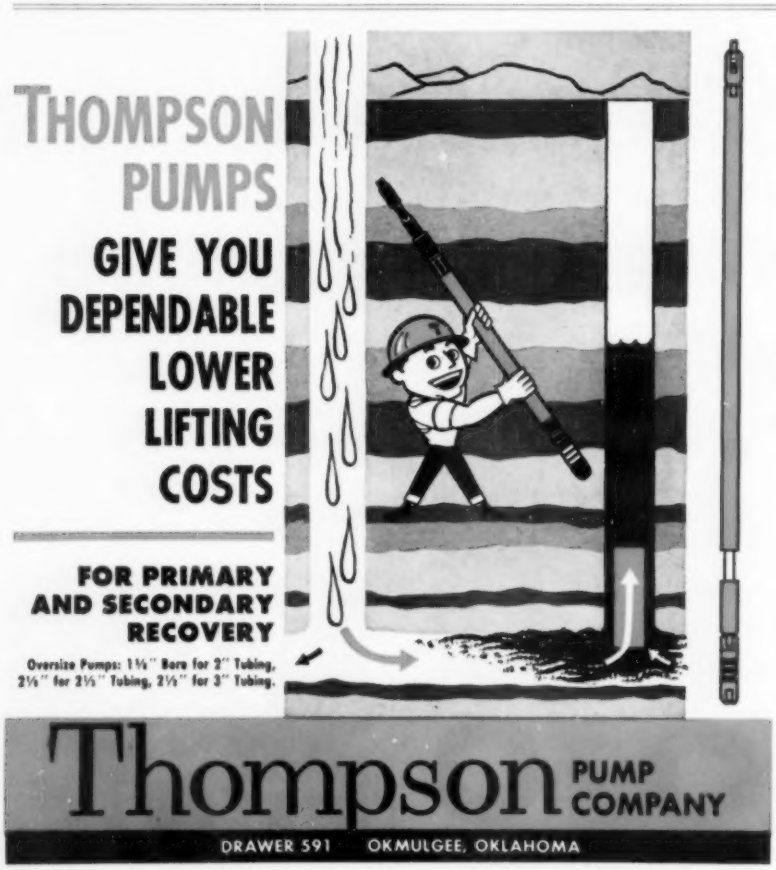
Four page, two-color Hydraulic Valve Actuator Bulletin VA-10 shows how Oil-Dyne designed an actuator to save space. It describes operation and oil field applications of newly-developed actuator in either direct or remote control. *Oil-Dyne, Inc.*

Circle number (13) on reply card.

Alarm Telemetering System

Brochure describes Alarm Telemetering System Model AT-100 which continuously monitors up to 50 alarm signals. A two-wire system transmits signals up to 20 miles and gives audible and visual alarms. *Instruments, Inc.*

Circle number (14) on reply card.



RUNNING TOUR with MEN in the INDUSTRY

▸ **A. B. Dyes,** former supervisor of reservoir engineering with the Atlantic Refining Company in Dallas, has joined the French firm of Géopétrole (Paris) as a consultant. Géopétrole offers services in exploration, formation evaluation, reservoir engineering and studies of underground gas storage.

▸ At Texaco, Inc., **C. Don Woodward,** senior petroleum engineer at the Bellaire Research Laboratories, is on leave of absence to serve as drilling superintendent aboard Global Marine Drilling Company's Cuss 1, which is on location off the Guadelupe Islands to drill the Project Mohole well. Water depth is about 12,000 ft.

▸ **Michael S. Reford** was named chief engineer geophysicist for Aero Service Group, a worldwide complex of integrated air survey companies.

▸ The American Association of Petroleum Geologists announced the following recipients of honorary membership: **Fritz L. Aurin,** Southland Royalty Company, Ft. Worth; **N. Wood Bass,** consultant, Fort Collins, Colorado; **Ralph E. Davis,** Ralph E. Davis Associates, Houston; **Vincent C. Illing,** V. C. Illing and Partners, London, England; **Theron Wasson,** senior geologist and advisor to the executive committee, Pure Oil Company, Chicago.

▸ **George M. Geyer,** superintendent for Cities Service Petroleum Company at Hobbs, New Mexico, was named chairman of the Southwestern District, API Production Division. He succeeds **Henry P. Kerr,** production manager for Delhi-Taylor Oil Company.

▸ **Karl S. Landstrom** has been designated new director of the Bureau of Land Management of the Department of the Interior, succeeding **Edward Woozley.**

▸ **J. A. Cleverley's** retirement as vice president-general manager of production for Cities Service Petroleum Company brings about several changes. **C. R. Smith** will succeed Cleverley; **J. P. Straight,** general superintendent of production succeeding Smith; **J. C. McClure** and **Don Kastner,** assistant general superintendents; **C. J. M. Russell,** chief petroleum engineer succeeds McClure.

▸ **Paul E. McGovney** has been elected vice president in charge of the exploration and production division for the Clark Oil & Refining Corporation.

▸ Continental Oil Company has announced the appointment of **M. H. Dubrow** as manager-production.

▸ A new exploration and production consulting company to be known as **Link Downing Cooke & Company Ltd.,** has been formed by Dr. Theo A. Link, J. A. Downing, and D. Y. Cooke, all formerly with Cree Oil Canada Ltd. & North Star Oil Ltd.

▸ **William J. Zabish** has been named division manager of Norwalk Oil Company's Sacramento Valley area, and **J. R. Trane** has been appointed division manager of the Fresno area.

▸ Two committee chairmen of the Oklahoma Petroleum Council have been announced: **John Steiger,** Cities Service Oil Company, Bartlesville, chairman of the historical committee of the council; and **S. D. Breitweiser,** president of the DX Sunray Oil Company, Tulsa, is chairman of the finance committee of the OPC's executive committee.

▸ **Lee Powell** and **W. E. Goad** have joined Ramsey Engineering, petroleum consultants in Oklahoma City. Powell was formerly with Texaco, Inc., Goad with Pan American Petroleum Corporation.

▸ **Ward W. Killingsworth Jr.,** has been named manager of drilling operations for The Shamrock Oil and Gas Corporation in Amarillo, succeeding **Joe Richardson,** who resigned to enter private business for himself.

▸ **James B. Taylor** has been appointed general manager of Signal Oil and Gas Company's gas department. **Paul Chambers** is his assistant; **R. L. Cook,** manager of operations; **Harvey Menard,** manager of joint interests; and **David R. Arnold,** manager of engineering and construction.

▸ **Theodore W. Nelson** of Westfield, New Jersey, has been named production manager of Socony Mobil Oil Company's exploration and production department.

▸ **Harold E. Rudel** was appointed assistant to the manager of the southwest producing division (headquarters in Dallas), and **Martin A. Row** was named special counsel for foreign operations in the production department of Sun Oil Company. Row succeeds **John W. Timmins,** who retired at the first of the year.

▸ **A. E. Meissner** has been named production manager of the Sunray Mid-Continent Oil Company's western division, headquarters in Corpus Christi, Texas.

Continued on page B-127

Target **ECONOMY • SERVICE • SAFETY**

There's no danger of over-buying when you specify W. C. Norris Well Head Equipment, for the Norris line is a complete line . . . with a wide range of tubing and casing heads engineered to meet your actual needs. Norris heads offer you high selectivity . . . true economy . . . without sacrificing design, service or safety. You can buy with confidence when you buy Norris. Write for prices and complete literature today!

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BRANCHES: Great Bend, Houston, Kilgore, Odessa, Wichita Falls, Salem, Casper, Farmington

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What's doing in DRILLING

Drilling Operations Merged Into Subsidiary Company

Tradewinds Exploration, Inc., Tulsa-headquartered oil and gas exploration company, announced it is combining all drilling operations into a new wholly-owned subsidiary called Tradewinds Drilling Company.

The action combines two former Tradewinds subsidiaries, Roden and McRae Drilling Company, and Warren Bradshaw Drilling Company, both of which have been contract drillers in the Mid-Continent and Rocky Mountain areas for the past quarter-century.

"Consolidation of the two subsidiaries, which will maintain present headquarters in Tulsa, will serve to identify operations more closely with the parent company," according to Bryce Crider, Tradewinds Exploration vice president and treasurer. No changes in personnel of either subsidiary are involved, he added.

Tradewinds Drilling will operate 16 rotary rigs in the Rocky Mountain and Mid-Continent areas, Crider said. Drilling operations are under the supervision of T. S. Rodgers at Casper, Wyoming, and J. L. Gilbert at Oklahoma City.

Mission Manufacturing Company Rig Survey Summary

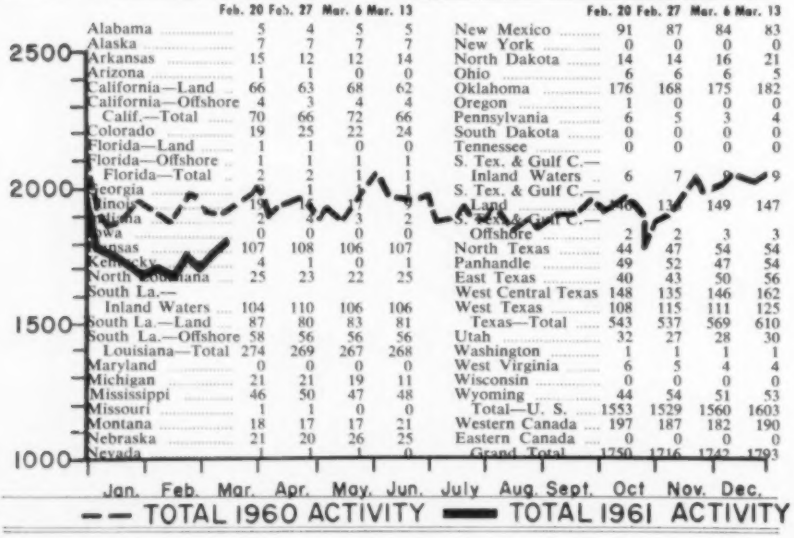
Location	Contractors	Rigs	Pumps	No. Rigs Stacked	Air Drlg.	Comb'n Air and Mud
Alabama	5	6	12			
Alaska	2	5	10			
Arizona	3	3	5	1		
Arkansas	9	11	17	1		3
California	54	153	307	19		
Colorado	25	34	47	6		4
Florida	3	3	5	1		
Illinois	41	58	58	18		
Indiana	15	20	20	3		
Kansas	85	144	154	67		
Kentucky	2	4	5	1		
Louisiana						
Houma Area	39	80	216	6		
Gulf Coast Area	50	94	257	3		
Northeast	8	12	18	4		
New Orleans	45	90	227	20		
Shreveport	24	41	74			
Michigan	24	48	68	8		
Mississippi	34	77	145	32		
Montana	6	7	14			
Nebraska	17	29	29	6		
New Mexico	65	131	197	33		16
North Dakota	3	6	12			
Northern Oklahoma	90	160	224	44		5
Southern Oklahoma	67	128	209	28		3
Oregon	1	1	2			
Texas						
East Texas Area	35	73	135			
Far West Texas Area	18	27	43	9		1
Houston Area	60	96	217	24		
Midland Area	65	125	220	12	1	9
North Texas Area	47	63	66	7		
Panhandle Area	53	98	151	37		
Snyder and Andrews	30	41	50	12		
Southwest Texas	63	97	299	25		
Texas Gulf Coast	45	70	191	4		
Utah	19	27	42	9		1
Wyoming	15	23	39	1		1
Canada						
Alberta	36	143	255	58		3
British Columbia	15	31	56	18		1
Ontario	1	1	1			
Saskatchewan	4	9	11	2		
Northwest Terr.	1	1	2	1		
TOTALS	877*	2270	4110	520	1	47

*Total Contractors operating in USA and Canada. Column totals to 1224 because of some contractors operating in more than one state. (Compiled January, 1961)

Rotary Rigs Operating in Oil Fields of United States and Canada

As reported to American Association of Oil Well Drilling Contractors by Hughes Tool Company.

	Feb. 20	Feb. 27	Mar. 6	Mar. 13
Alabama	5	4	5	5
Alaska	7	7	7	7
Arkansas	15	12	12	14
Arizona	1	1	0	0
California—Land	66	63	68	62
California—Offshore	4	3	4	4
Calif.—Total	70	66	72	66
Colorado	19	25	22	24
Florida—Land	1	1	0	0
Florida—Offshore	1	1	1	1
Florida—Total	2	2	1	1
Georgia	0	1	1	1
Illinois	1	1	1	1
Indiana	2	2	3	2
Iowa	0	0	0	0
Kansas	107	108	106	107
Kentucky	4	1	0	1
North Louisiana	25	23	22	25
South La.—				
Inland Waters	104	110	106	106
South La.—Land	87	80	83	81
South La.—Offshore	58	56	56	56
Louisiana—Total	274	269	267	268
Maryland	0	0	0	0
Michigan	21	21	19	11
Mississippi	46	50	47	48
Missouri	1	1	0	0
Montana	18	17	17	21
Nebraska	21	20	26	25
Nevada	1	1	1	0
New Mexico	91	87	84	83
New York	0	0	0	0
North Dakota	14	14	16	21
Ohio	6	6	6	5
Oklahoma	176	168	175	182
Oregon	1	0	0	0
Pennsylvania	6	5	3	4
South Dakota	0	0	0	0
Tennessee	0	0	0	0
S. Tex. & Gulf C.—				
Inland Waters	6	7	9	9
S. Tex. & Gulf C.—				
Land	136	134	149	147
S. Tex. & Gulf C.—				
Offshore	2	2	3	3
North Texas	44	47	54	54
Panhandle	49	52	47	54
East Texas	40	43	50	56
West Central Texas	148	135	146	162
West Texas	108	115	111	125
Texas—Total	543	537	569	610
Utah	32	27	28	30
Washington	1	1	1	1
West Virginia	6	5	4	4
Wisconsin	0	0	0	0
Wyoming	44	54	51	53
Total—U. S.	1553	1529	1560	1603
Western Canada	197	187	182	190
Eastern Canada	0	0	0	0
Grand Total	1750	1716	1742	1793



Mission breaks down their survey in such a way as to indicate rig location by county. It also shows the rig's owner, number, size and make of pumps. In addition, survey shows whether the rig is stacked or operating and whether it is capable of air drilling or a combination of air and mud drilling.

Russian Reports Claim Ultra-Deep Drilling

If any credence can be given what the Russians say about their own technical progress, they're doing some mighty deep drilling these days. Soviet sources in recent months, particularly radio broadcasts and newspaper stories, have disclosed some amazing achievements in deep drilling.

Most of Russia's production comes from relatively shallow depths: from 5500 to 6000 ft. Early in August, 1960, Soviet news sources reported reaching

a new producing depth of 4895 meters (16,060 ft). Several announcements recently indicated Soviet intentions to drill even deeper wells. One report called for drilling to a depth of 8000 to 10,000 meters (30,248 to 32,810 ft).

Whatever their techniques are and how long it takes Russian drillers to reach these depths, no word is mentioned. But, it is apparent that Russians have found what U. S. operators learned long ago . . . that new oil horizons do exist at the deeper depths. And, Russia, like the U. S., is stepping up its deep drilling activities.

Offshore Company Using New Modern Platform

A new mobile, self-elevating deep-water drilling rig has been added to the fleet of The Offshore Company and placed in service off the coast of British Honduras. Designated as Offshore Rig 58, it is drilling about 75 miles south of Belize, capital of the British crown colony and nine miles offshore in the Caribbean in 22-ft deep water.

API Speakers Attack High Drilling Costs

Delegates to the recent Mid-Continent District meeting of the American Petroleum Institute's Division of Production were warned that they must find new ways of reducing costs involved in the drilling and completing of oil and gas wells.

Warren L. Baker, AAODC executive secretary, told a group session of the meeting that what is good for operators is good for contractors. He declared that both parties must have as their goal "a reduction in overall costs —pushing responsibilities and bills from one party to the other will not achieve needed economies." Baker asked specifically for lower costs resulting from large number of bid requests, inadequate bid specifications, and unnecessary requirements on equipment.

Another speaker at the meeting, T. E. Watkins, Socony Mobil Oil Company, Inc., reported on a new drilling fluid designed to reduce drilling costs. He described development of an inverted-emulsion completion and drilling fluid with the following features: it is resistant to various contaminants and to high temperatures; it can be prepared and controlled by comparatively inexperienced field personnel; it does not require big-rig mixing equipment for preparation. Watkins told a meeting of the Drilling Practice Committee that the emulsifier greatly broadens the utility of such fluids.

Future of the oil industry was previewed by a panel whose cumulative industry past totals 155 years at the Dallas-Fort Worth Chapter AAODC meeting late in March. Left to right are: Eugene McElvaney, senior vice president, First National Bank, Dallas; John B. O'Connor, president, Dresser Industries, Inc., Dallas; John Moran, AAODC president and president of Moran Drilling Co., Wichita Falls, Texes; and W. Dow Hamm, vice president, Atlantic Refining Co., Dallas. J. Mark Gardner, vice president, Delta Drilling Co., not shown, was moderator.

5 months of sand production fail to damage

CAMCO

Straight-Thru Design

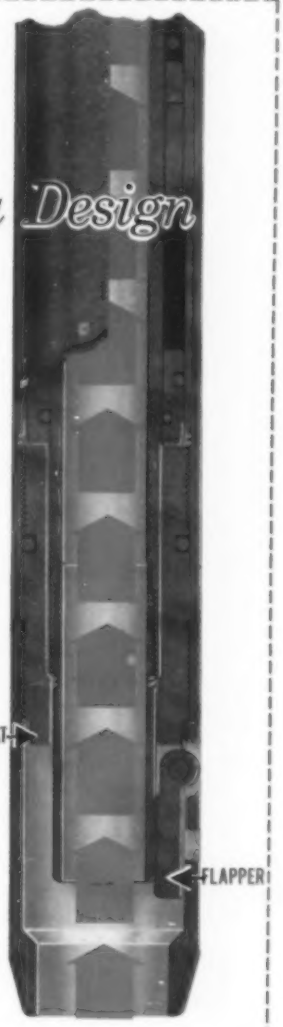
A-2 TUBING SAFETY VALVE

In a South Louisiana well, heavy sand production had repeatedly cut out subsurface tubing safety valves of conventional design, necessitating replacement every 60 days.

Then a Camco *Straight-Thru* design A-2 Safety Valve was installed. By its large straight bore and by location of the flapper and flapper seat outside the flow stream, *Straight-Thru* design reduces flow turbulence and protects vital seating surfaces against sand cutting. Pulled from the sand-producing well five months after installation, the Camco A-2 Safety Valve was found to be in perfect condition—ready for further duty!

Constant operating readiness for long periods of service make the Camco *Straight-Thru* A-2 your most reliable, positive assurance of automatic shut-in if surface controls should fail.

Your CAMCO representative will gladly tell you more about ***Straight-Thru*** *design and the other advanced features of A-2 Tubing Safety Valves. Ask him, or write for a complete brochure.*



Straight-Thru design reduces turbulence, protects valve seating surfaces against abrasion, assures proper closure of valve at predetermined pressure drop.

CAMCO

"PRODUCING PETROLEUM PROGRESS"

CAMCO, INCORPORATED

Box 14484, Houston 21, Texas

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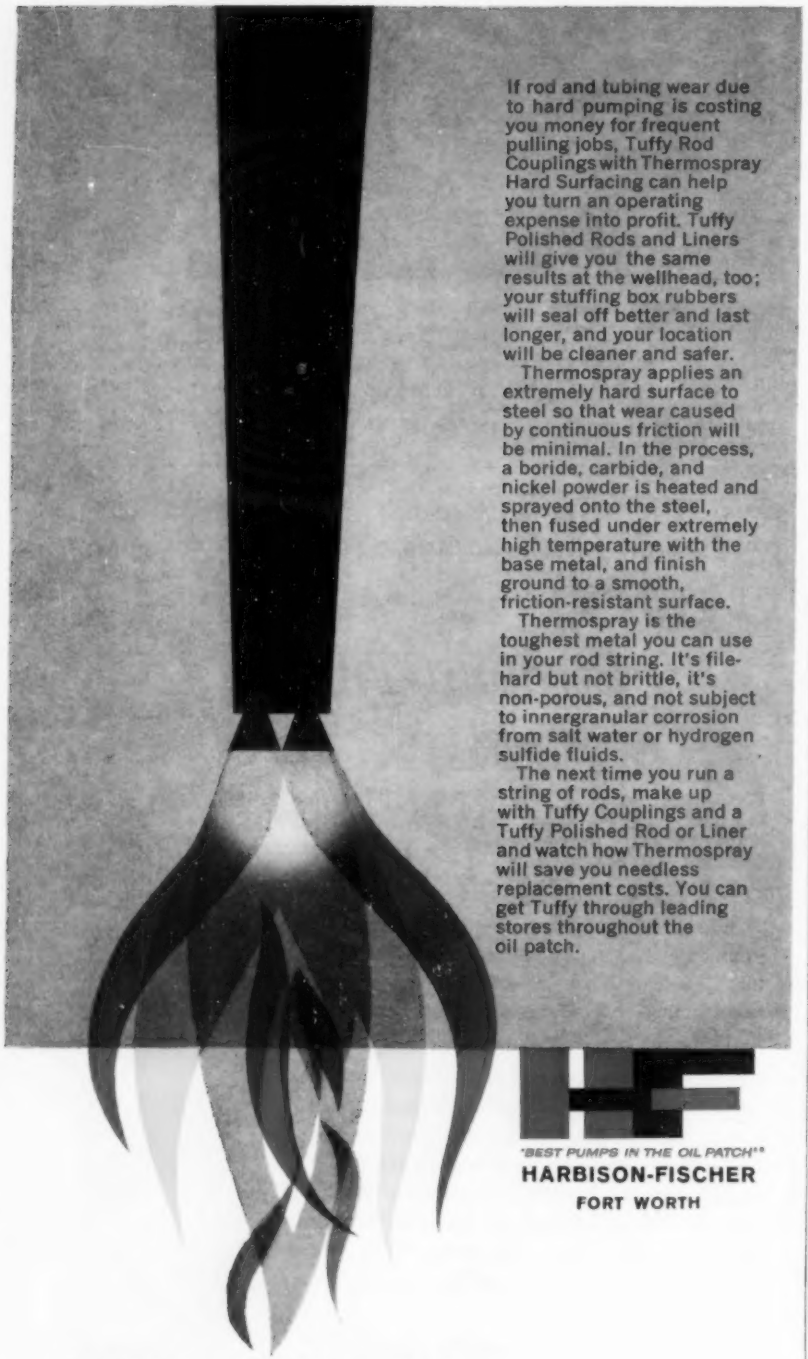


If rod and tubing wear due to hard pumping is costing you money for frequent pulling jobs, Tuffy Rod Couplings with Thermospray Hard Surfacing can help you turn an operating expense into profit. Tuffy Polished Rods and Liners will give you the same results at the wellhead, too; your stuffing box rubbers will seal off better and last longer, and your location will be cleaner and safer.

Thermospray applies an extremely hard surface to steel so that wear caused by continuous friction will be minimal. In the process, a boride, carbide, and nickel powder is heated and sprayed onto the steel, then fused under extremely high temperature with the base metal, and finish ground to a smooth, friction-resistant surface.

Thermospray is the toughest metal you can use in your rod string. It's file-hard but not brittle, it's non-porous, and not subject to innergranular corrosion from salt water or hydrogen sulfide fluids.

The next time you run a string of rods, make up with Tuffy Couplings and a Tuffy Polished Rod or Liner and watch how Thermospray will save you needless replacement costs. You can get Tuffy through leading stores throughout the oil patch.

"BEST PUMPS IN THE OIL PATCH"
HARBISON-FISCHER
FORT WORTH

NEW from Harbison-Fischer

tuffy

POLISHED RODS
POLISHED ROD LINERS
SUCKER ROD COUPLINGS
with H-F

thermospray

HARD SURFACING

B-118

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

SUPPLIERS' PARADE

New Companies, Subsidiaries, and Agents

Burgess-Manning Company of Dallas has formed a new subsidiary—Burgess-Manning International S. A., Paris, France. Under the direction of Jean B. Dumon, BMI will function in France and Western Europe on a line similar to Burgess' American operations.

A new valve servicing and repair division with plants and offices throughout the country has been announced by **Crane Company.** The first of the new division's facilities is now in operation in Chicago, with plants scheduled for Houston, and Los Angeles.

Daniel Orifice Fitting Company has appointed the American Premaberg Company, Inc., and its subsidiary companies representatives for Daniel products in England, France, Germany, Austria, Italy, Spain, Algeria and the Netherlands.

New representatives for **Grant Oil Tool Company** have been announced: S. N. Marep—France, North Africa and the franc area countries; Macridge Petroleum Equipment Supply Company—Lebanon and the Middle East; and Drillex, Argentine.

INELCO or **International Equipment Leasing Company** has been formed to purchase and lease all types of production equipment to the oil and gas industry. Organizers of the new company are J. M. Lebeaux, Houston, and Bruce and Curtis Calder, Jr., of Dallas.

Jones and Laughlin Supply Division has been appointed distributor of hydraulic subsurface pumps manufactured by **Johnson-Fagg Pump Company** of Tulsa.

Sherkat Sahami Magcobar Iran, a new affiliate of **Magcobar Division of Dresser AG,** headquartering in Teheran, has started-up a drilling mud production facility. The new organization produces Magcobar drilling mud weight material and lost circulation products.

Minnesota Mining and Manufacturing Company has formed a manufacturing subsidiary, Minnesota Manufacturera y Mercantil S.A. in Bogota.

Parker-Hannifin Corporation has appointed Truck Parts & Equipment, Inc. of Houston distributor for Parker industrial hose and reusable hose fittings.

Eastman Equipment Company of San Jose is a new distributor for **Worthington Corporation's** full line of air and water cooled compressors.

Appointments and Promotions

American Iron and Machine Works Company, Inc.—**M. G. McCool,** resigned as president.

C. L. Griffin

Chicago Pneumatic Tool Company —**C. L. Griffin,** general manager-oil tool division replacing **G. A. May,** appointed executive vice president-general manager of Allen Manufacturing Company, a Chicago Pneumatic affiliate.

Armour Industrial Chemical Company —**L. M. Miller,** sales manager, industrial chemicals; **E. L. Rhoads** western regional

manager will relocate office to Los Angeles from Portland, Oregon; **C. D. LaSusa,** sales manager of petroleum chemical sales, Dallas.

Avondale Shipyards, Inc.,—**Jim Milsted,** sales engineer of oil tools department, New Orleans.

Camco, Inc.—**Sam W. Pearce,** senior vice president; **Cecil B. Greer,** vice president-sales; **Gilbert H. Tausch,** vice president-research and engineering; **Albert A. Hughes,** vice president-production.

C-B/Southern — **Jack Mershon,** area sales manager-Mid-Continent area.

Continental-Emsco Company—**Roscoe O. Hambric,** marketing manager, and **Harry Hobbs Jr.,** merchandising manager, and **Robert M. Erskine,** sales manager—machinery and miscellaneous merchandise; **Joe Martin,** manager—production machinery sales.

Daystrom Inc. — **Douglas M. Pogue,** chief systems analyst—gas and oil, and **Robert Hooper,** systems engineering coordinator, control systems division, **Ralph L. Shapcott,** director of manufacturing and assistant general manager, and **James W. Harte Jr.,** service division manager, Weston Instruments Division.

Grove Valve and Regulator Company —**Arnold H. Stephens,** Southern California district manager of sales.

Hunt Tool Company—**Robert R. Sloan,**

Continued on page B-122

World's Largest Junk Basket Sent To Iran

World's largest junk basket, designed and manufactured by Bowen-Itco, was recently shipped to the oil fields of Iran. This giant reverse-circulation type junk basket measures 22-in. OD and retrieves a 17-in. core with a 23-in. OD mill shoe. Tool fishes in a 26-in. hole.

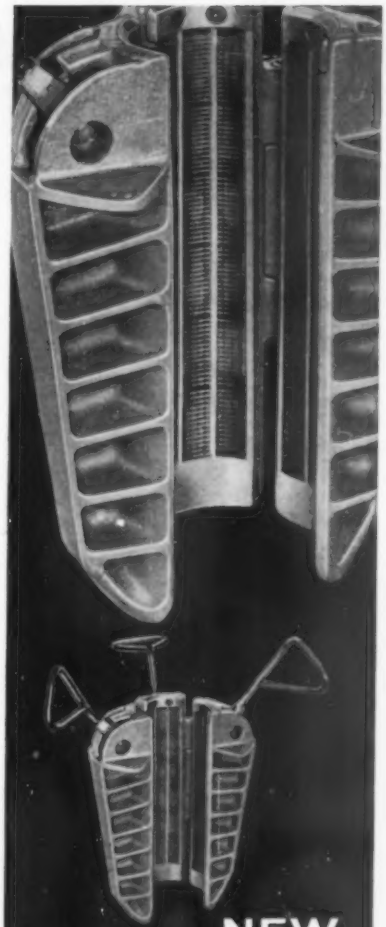
Domestic operators seldom use this size oil tool, since they drill smaller holes. Bowen-Itco manufactures standard junk baskets ranging in size from 3⅝ in. through 15 in., shown on either side of giant tool, but higher production rates in overseas operations requires drilling larger holes.

Fishing crews lower reverse-circulation junk baskets into hole to retrieve all types of debris which gathers from bit failures, milling jobs, or else drops down hole accidentally. Junk baskets have a long, hollow barrel designed to collect these objects and retain them as crew raises basket on return trip.

Bowen-Itco custom-manufactures specialized oil tools used in fishing, drilling, completions, and wire line services to meet specified dimensions. They designed and manufactured world's largest spear less than a year ago and shipped it also to Iran.

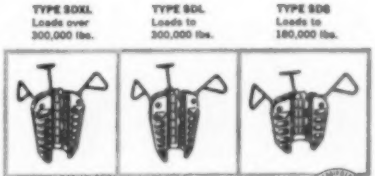
Firm maintains 21 sales, service and warehouse facilities throughout oil and gas producing areas of North America, and export agents represent them in other oil areas of free world. *Bowen-Itco, Inc.*

Circle number (15) on reply card.



NEW
Varco
ROTARY SLIPS

Modern metallurgy and design make them strongest and safest
—yet they weigh no more than ordinary slips! Varco Type SDXL has 45% longer supporting back for deeper drilling. New inserts, with greater line contact, grip better; cannot be knocked out accidently. But you can replace them quickly with circular buttons for rotating drill pipe.



WRITE FOR LITERATURE

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LOS ANGELES 54, CALIFORNIA
MIDCONTINENT OFFICE: HOUSTON, TEXAS

EXPLORATION ACTIVITIES

BELGIUM

First Full-Scale Licenses Allow Petroleum Prospecting

Belgium has issued the first two full-scale licenses authorizing petroleum prospecting in the country.

One tract covers about 1450 square miles and was awarded to Ste. Champenoise de Recherches et d'Exploitations Minerales, known as SCREM. Seven Belgian coal companies formed the group and contracted with Petrofina to explore the acreage.

This tract is bounded by the Netherland border on the north and the Meuse River on the east. It includes areas of Antwerp, Limburg, and Brabant provinces.

Second concession went to a Royal Dutch Shell company, Bataafse Petroleum Mij. Their rights cover about 1015 square miles in Namur, Hainaut, Liege, and Luxembourg provinces in southern Belgium.

Both concessions remain in force for 50 years.

CALIFORNIA

Deep Gas Well Test Spudded To Speed Developing Field

A deep test gas well in the West Grimes area of northern California's Sacramento Valley will accelerate development of the field. Occidental Petroleum Corporation spudded in the well as a westerly offset to their Sachreiter No. 1 and a southwesterly offset to Sachreiter No. 2, both completed as prolific gas producers.

Occidental located the drill site on the southwest quarter of Section 4, Township 14 North, Range 1 West, Colusa County.

Company will explore the Upper Cretaceous F zone sands to a depth of at least 9000 ft, exceeding deepest well yet drilled in the field.

Fourth Straight Discovery Flows In Helm Field Acreage

Fourth straight discovery without a dry hole in the Helm field of Fresno County, California, produced 214 bbl of 35 plus gravity oil per day through a 9/64-in. bean. Nordon Corporation Ltd.'s Noble 4-9 well registered 940 psi on the tubing with none on the casing.

A 5½-in. liner was installed, then well was perforated between 6852 and 6858 ft to 6861 to 6864 ft. Oil flows from the Miocene zone.

Nordon expects to drill ten more wells at a one-a-month rate during the present exploration program to prove their 650-acre lease block at Helm field.

LIBYA

Three Wells Underway In Cyrenaica Province

BP Exploration Company continues drilling their second test well in Tripolitania province of Libya. This well in concession 34 has reached a depth of some 6400 ft.

A test further east in concession 36 has now reached 7700 ft and another well in concession 80 of southern Cyrenaica turned out dry at total depth of 9694 ft. BP will move this rig into the adjoining area to drill the first deep test in concession 81.

First well underway in concession 65 in the southern part of the province has reached 7400 ft. BP plans drilling up to six wells here in partnership with Nelson Bunker Hunt.

Six seismic parties continue studying Libyan prospects.

LOUISIANA

Two New Productive Sands Hit in East Hackberry Field

A Pan American Petroleum Corporation well discovered two new productive sands for the north flank of the East Hackberry field in Cameron Parish, Louisiana. No. 54 Gulf Land A R/A C found 256 ft of total pay in four zones and will be dually completed in the Camerina D and Camerina C zones, both new to the area.

Well flowed 182.88 bbl of oil per day and 329 Mcf per day of gas on an 8/64-in. choke in the Camerina D sand. It was perforated between 11,032 to 11,038 ft and 11,060 to 11,070 ft in the Camerina C sand. On a two hour test it flowed 299.16 bbl of oil per day and 335 Mcf of gas per day on 8/64-in. choke.

Total depth of the well was 11,942 ft and it was plugged back to 11,330 ft.

30 Well Drilling Program Planned for Sligo Flank

Shell Oil Company plans to drill 30 wells on the undeveloped flank of the Sligo oil field lying on Barksdale Air Force Base lands in Bossier Parish, Louisiana.

Sligo field adjoins the base, and Shell bid successfully on the two tracts totalling 3500 acres at a lease sale last December.

Program calls for 52 drainage points in these wells to reach seven expected formations between 3000 and 8500 ft. Operators have found 14 producing horizons in the presently-developed areas of the 39-year old field.

Drilling won't hamper flying operations, since five miles separates the acreage from the landing strips. Unexploded anti-personnel bombs could pose a threat, however, even though base officials have combed the area and pronounced the former bombing range safe.

NEW MEXICO

San Juan Basin Wildcat Will Drill to Basement

El Paso Natural Gas Company is now drilling on a deep wildcat in the San Juan Basin of northwest New Mexico. Located about 35 miles east of Farmington, the well will go to the basement. Only one well has been drilled this deep, and it was on the eastern edge of the basin.

Dakota sandstone production continues under development in the San Juan Basin, and any good indications below could result in a revival of drilling in this vast area characterized by its gas production. El Paso holds about 200,000 acres in the vicinity of the deep wildcat.

OKLAHOMA

Second Deepest Producer Completed in Several Zones

Oklahoma's second deepest producing well flowed 6050 Mcf per day of gas with 9.2 bbl of 47 degree gravity condensate per hour on a six hour flowing test. Gulf Oil Corporation and associates completed the No. 1 E. L. Wood in Grady County to produce from several intervals between the depth of 16,180 ft and 16,376 ft in the Springer formation. This well became the deepest Pennsylvanian production ever found in the state.

Flowing tubing pressure read 3910 psi and shut-in pressure 8557 psi through a 13/64-in. choke. Gulf drilled the wildcat to 17,000 ft total depth and set casing to 16,605 ft.

OHIO

State Publishes New Map Of Known Oil and Gas Pools

Ohio has published a revised map of their oil and gas fields which shows by color the extent of all known pools in the state. A table at the bottom of the map gives field names, date of discovery, producing horizons, and depth to producing horizons. Map also includes a generalized section on Ohio's rocks

which gives both geologic and driller's names of state's bedrock formations.

Division of Geological Survey in Columbus, Ohio, prepared the map.

Well In Hocking County Flows Oil, Gas During Test

A well on the Val Wolfe lease in Falls-Gore Township of Hocking County in Ohio flowed 100 bbl of oil and 1200 Mcf of gas in 12 hours.

Stewart Oil Company brought in and fractured the well after drilling it to a total of 2832 ft. Production comes from a 12 ft band of Clinton sand found at 2794 ft.

SYRIA

Country Invites Bids On 20 Oil, 3 Gas Wells

Syrian Region of the General Petroleum Authority, United Arab Republic, has invited bids for drilling 20 oil wells and 3 gas wells.

This request includes 3 exploratory and 17 development wells between 6000 and 11,500 ft in depth which the country wants drilled in the Qarah Shuk oilfields, and 3 gas wells between 1800 and 4800 ft in the Jezirah area.

Syria nationalized some production from private operators less than three years ago, charging violations of their drilling agreement. Russian drilling equipment is reportedly operating in the country, and a West German firm is conducting evaluation work at Suwaidiyah.

TEXAS

Gulf Coast Report Lists Monthly Farmouts, Leases

New report service publication, Farmout and Lease Listing Service, provides a monthly report of farmouts, unleased acreage and producing properties available in the Gulf Coast area.

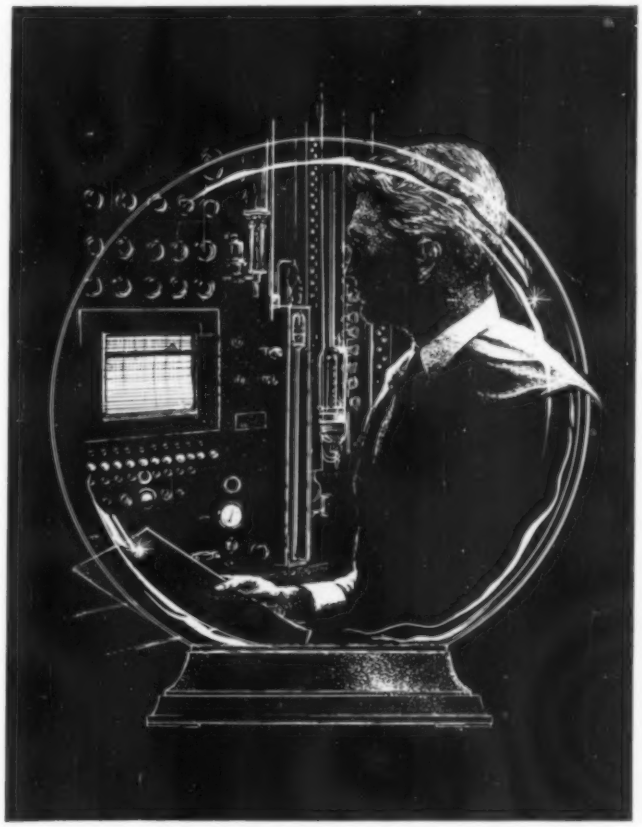
W. E. Failing, until recently area scout for Humble Oil and Refining Company in the Texas Gulf Coast and chairman of the executive committee of the Gulf Coast Scouting Association, heads the operation. He resigned both positions to organize the FALLS report.

THAILAND

$5 Million Program Planned For Petroleum Exploration

Thailand will spend about $5 million for a three year geological survey seeking petroleum. Plan calls for a gravimeter survey during the first year, a seismograph survey the second, and drilling operations in the third.

Oil Fuel Organization, Ministry of Defense, in Bangkok heads the program.



know your reservoir... know your future

The state of hydrocarbons within a reservoir is not always apparent from surface production.

Each zone has its own unique fluid make-up. And to maintain an optimum balance between this "productive personality" and the operator's desired income, it is necessary to establish pressure-volume-temperature data *early* in the life of key wells.

From Core Lab's Reservoir Fluid Analysis Reports you can estimate, with reasonable accuracy, the quantity of oil in place and the amount you may expect to recover, and inaugurate the most effective field procedures.

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FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

general manager, Houston Engine and Pump Company.

Hughes Tool Company—three assistant vice presidents elected to board of directors: **Park L. Myers,** sales; **Lyle L. Payne,** engineering; **Arthur H. Wooler,** manufacturing.

Joy Manufacturing Company—**Kenneth M. Grover,** field sales specialist—turbodynamic products; Oregon, Washington and California.

Ludlow Valve Company—**Robert L. Wilkinson,** central regional manager, formerly with Tube Forgings Company.

Merla Tool Corporation—**C. D. Fletcher** retired; **Lewis J. Bicking Jr.,** sales manager.

Nalco Chemical Company—**M. C. Griffin,** manager of Mid-Continent region for Visco Products Company, Nalco subsidiary.

National Supply Division, Armco Steel Corporation—new store managers: **H. F. Dunaway,** Big Spring; **Oran D. Nash,** Abilene; **Herbert N. Seigler,** Wichita Falls; **Robert L. Vingoe,** chief field engineer — tubular department, succeeding **Charles C. Bush,** who was appointed field engineer, Houston.

Nocor Chemical, Inc.—**Robert Edward Thee,** corrosion engineer.

W. C. Norris Division, Dover Corporation — **Anthony J. Ormsby,** secretary-treasurer.

Oil Center Tool Company—two sales representatives transferred: **Kenneth W. Sewell,** Dallas; **James J. Humphries,** Houston; two new district sales managers: **B. G. Barefield,** Rocky Mountain region; **Jerry Boyd,** Four Corners area.

OPW Corporation—**William J. Brown,** district manager—Rocky Mountain area.

Otis Engineering Corporation—**J. L. Pearce,** sales engineer, Otis Pressure Control, Inc., Canadian division.

OTC Tools & Equipment—**Ralph W. Long,** Central California district sales representative.

Pennant, Inc.—**W. G. Pitzel,** sales and service representative, working with salesmen of Bradford Motor Works, a Pennant distributor.

Pipe Linings, Inc.—two new vice presidencies: **Bert Espiau,** general administration; **Donald N. Chamberlain,** sales and civil engineering.

Pittsburgh Chemical Company—**B. L. Sharp,** sales representative, pipeline coatings and related products.

Plastic Applicators, Inc.—**John Lubke,** production superintendent, Pipe Inspectors Division, Odessa.

Plumb Supply Company—**Lou Trisler,** sales manager, Oil Equipment Division, formerly with Gibson Pump and Equipment Company, Des Moines.

Robertshaw-Fulton Controls Company, Fulton Sylphon Division—**George L. Ogdin Jr.,** general sales manager.

Rockwell Manufacturing Company—**Thomas J. Williams,** branch manager—El Paso, Texas.

Smith Industries, Inc.—**N. S. Kendall,** assistant to president.

Tyson Smith Company—**John Erwing,** process engineer, Houston; **William W. Chapman,** sales and service, Pampa, Texas.

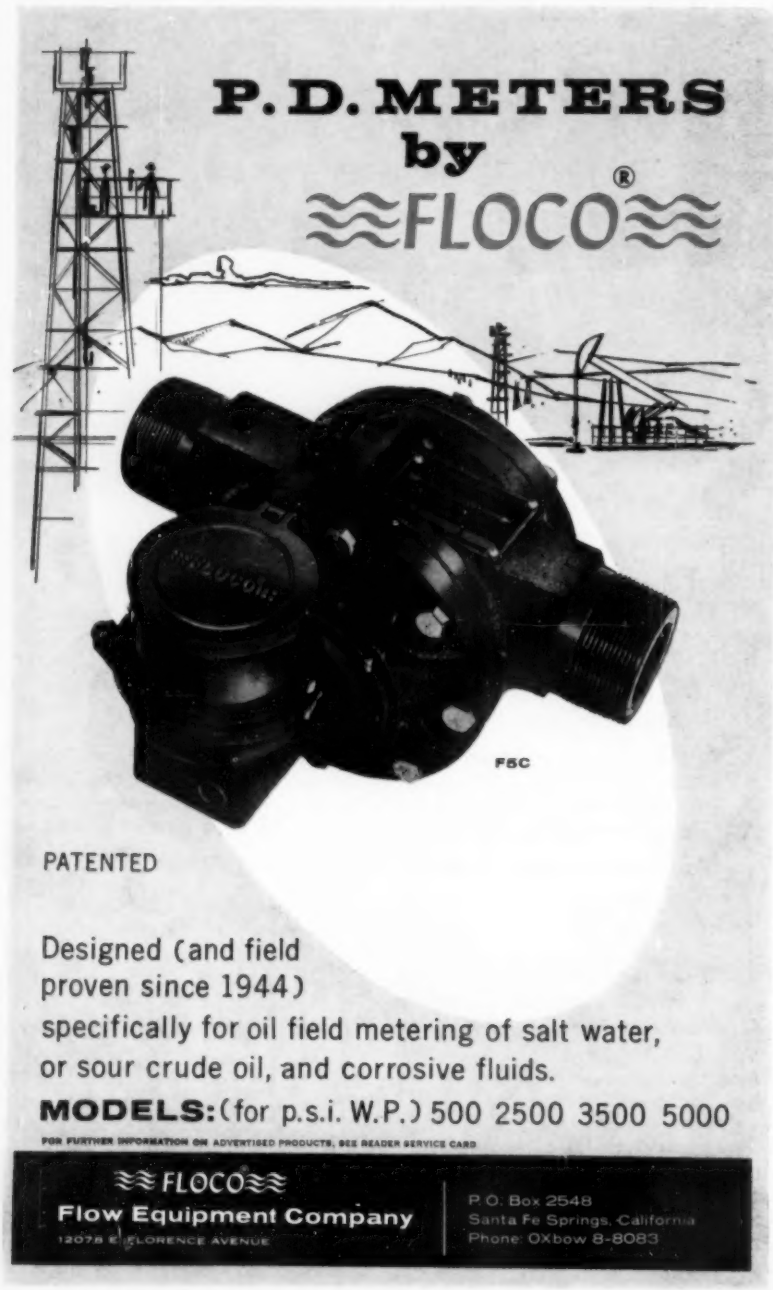
Udell, Inc.,—**D. E. Whittenberg,** vice president—marketing manager, formerly with Garrett Tool Oil.

U. S. Industries, Inc., Axelson-Garrett Division—**J. P. Nielsen,** product sales manager—pump and sucker rod lines; **W. K. Woodward,** sales administration manager—material controls, sales engineering and export sales.

United States Steel Corporation, Oil Well Supply Division—**Daniel H. Barr,** assistant vice president—marketing; **Robert H. Smith,** director—product service; new managers: **Robert E. Dickson,** sales—Central Midwest area; **William Miskimins,** store products.

Valley Manufacturing Company—**Robert E. Finnman,** vice president, sales—steel pipe division.

Worthington Corporation—**Lewis M. Evans,** Eastern region resale sales manager, marketing division; **William A. Finn,** vice president-Group, succeeded as vice president-general manager of Harrison Division by **A. Edwin Carter; John A. Malsi,** central region resale sales manager, succeeding **F. J. Reardon,** appointed Eastern zone manager, construction equipment division.



General News

The **Cabot Corporation,** machine division, has selected Houston as headquarters for its export sales division, with Clyde Lackey as export sales manager.

Continental-Emsco Company opened a new supply store in Hennessey, Oklahoma, with Bob Hull as manager.

BJ Service, Inc., has opened new field stations in Robstown and Three Rivers, Texas. Jim B. Gardner will act as regional sales supervisor and Werner Hartman as district superintendent.

Dowell Division of Dow Chemical Company is now furnishing their cus-

tomers with an electronic data computer service. Well and pool information related from the Dowell service engineer to the computer center in Tulsa will permit computations to be made and returned to the sender in minutes, information that normally takes from 8 to 12 hours using a slide rule or desk mechanical calculators.

Eastern Malleable Iron Company of Naugatuck, Connecticut, along with one of its major divisions, Eastern Sales Company, has changed its name to the **Eastern Company.**

Hardy-Griffin Engineering Corporation, a division of Atlas Bradford Company, opened a new district sales office in Dallas with David J. Gent in charge.

Allen F. Rhodes, vice president of engineering and manufacturing of the **McEvoy Company,** was asked to present a paper, relative to pressure-energized high pressure gaskets, before the International Conference on Fluid Sealing of the British Hydromechanics Research Association in Ashford, Kent, England, during April.

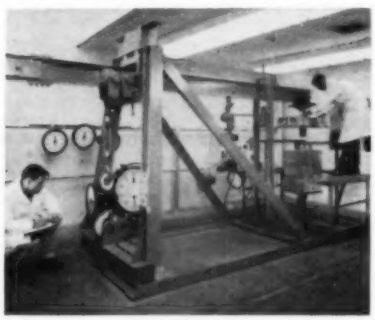
National Supply Division of Armco Steel Corporation has opened a new oil field supply store in McCook, Nebraska. V. R. Graham, will be store manager.

Union Carbide Olefins Company division of Union Carbide Corporation, has opened sales offices in Chicago, and Memphis. Their Cleveland office has been in operation now for several months.

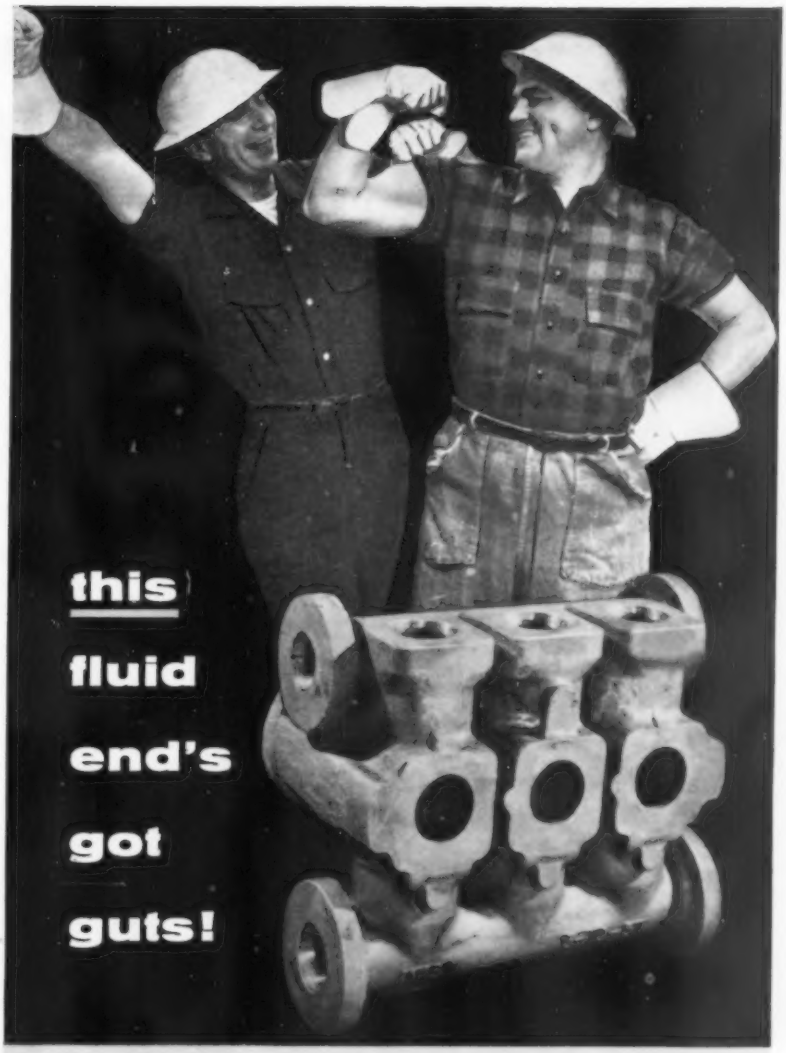
Cal-Metal Pipe Corporation of Louisiana has changed its name to **Stupp Corporation.** It will be operated by a wholly-owned subsidiary of Stupp Brothers Bridge & Iron Company, Stal St. Louis.

Formation of a new laboratory at **The Dow Chemical Company,** known as Instrument Systems Research Laboratory was announced. The lab will assist all Dow groups, including research, engineering and production, with problems relating to instruments and instrument applications.

The Kraloy-Chemtrol Company has opened a district sales office and warehouse in Philadelphia, as part of an expansion program to meet the increasing use of industrial plastic products in the Eastern market. Stowe Shoemaker will head the new facility.



A new temperature controlled and dust free calibration and standards laboratory was opened by **Martin-Decker Corporation** in Long Beach, California. It includes this single lever weigh beam, designed and built by the company since conventional equipment is not capable of the precise mass and force measurements made at the new laboratory.



It's cast of AMPCO® metal
...even salt water can't damage it

Tough pumping conditions are duck soup to Ampco metal. It's a two-fisted aluminum-bronze alloy that is specially engineered to guard against failure caused by corrosion, erosion, abrasion, and cavitation-pitting. It provides exceptional strength — yet it weighs 10-15% less than ordinary bronzes.

Check for this protection when you look at specifications of duplex and triplex pumps. And — insist on fluid ends of Ampco metal for replacements on your old pumps.

Send coupon today for further information on Ampco metal in corrosive applications.

AMPCO METAL INC., Milwaukee 1, Wisconsin

West Coast Div.: Huntington Park, Calif. • Southwest Div.: Garland (Dallas County), Texas

AMPCO METAL, INC.
Dept. 4415
Milwaukee 1, Wis.

Send me Bulletin on Ampco metal

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Nowadays
to make a
PROFIT
You've Got to Cut
COSTS
For Deep Production or Shallow

METAL PUMP	BMW NU-TEX
① Price	
$541.37	—$285.56
② Production	
72 Bbls	—87
③ Repair Cost	
$147.80	—$61.50
④ Pulling Cost	
———	SAME
⑤ Pumping Power Cost	
———	SAME

Adds up to

PROFIT
Multiplied by number of wells on your lease.
and don't throw away your old pump . . .
CONVERT IT!
Specify only BMW at your Supply Store.

OUR 50th YEAR

The only manufacturer of Soft Packed Pumps Exclusively

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BRADFORD MOTOR WORKS

BRADFORD MOTOR WORKS
General Office and Factory
Bradford, Pennsylvania
Branch Office and Factory
Tulsa, Oklahoma
Warehouse
Odessa, Texas
Excell Specialty Co.
Edmonton, Alberta, Can.

It's New Drilling-Producing Equipment

Tubingless Completion Tools

T-I-W Type AH Packer for tubingless completions features automatic bottom which eliminates left-hand rotation of tubing while setting or releasing. Packer features a one-piece mandrel and ring-type packing element designed for positive seal against high pressures. It comes with (1) or without hydraulic hold-down slips (2). RLO Tubing Safety Joint (3) features a friction ring to facilitate easy release. Tubing Centralizer (4) permits running multiple strings of tubing individually while maintaining proper annular spacing. Double Box Tubing Landing Collar (5) provides a pressure seal where desired, Double Type Tubing Wiper Plug (7) or Ball Type Tubing Wiper Plug (8) latches into landing collar when pumped down tubing during cementing. *Texas Iron Works.*

Circle number (16) on reply card.

Oil Thief

Curtin designed a different type of Oil Thief which uses a full-opening, side-mounted shutter valve. Easily cocked, a slight pull trips the thief. It uses 2-in. barrels graduated in ¼-in. divisions and comes in a variety of materials and four sizes—12, 16, 18, and 24 in. *W. H. Curtin and Company.*

Circle number (17) on reply card.

Clarifier-Filter Unit

Hagan introduced a pilot plant clarifier-filter unit for gathering essential data in designing water treatment plants. Skid-mounted, portable unit consists of clarifier; surge tank; optional anthracite or diatomite filters or both; a flow meter; and five chemical feeders for coagulants, coagulant aids, filter floc, corrosion inhibitors, or biocides as treatment may demand. Bradford Laboratories engineers evaluate leased unit for operating requirements. *Hagan Chemicals and Controls, Inc.*

Circle number (18) on reply card.

Remote Pressure Indicator

A redesigned Teledyne 236 Pressure Indicator gives remote readings from 0 to 10,000 psi with proper calibration. Compact, integrated 4½-lb, 115-volt instrument consists of a voltage-regulated 60-cycle power supply for excitation of strain gage bridge, an amplifier power supply and a transistor amplifier to increase voltage level of bridge output to dc meter movement. Firm designed it to operate with their Teledyne Bonded Strain Gage Pressure transducers. *Taber Instrument Corporation.*

Circle number (19) on reply card.

Marsh Funnel Viscometer

Baroid's plastic Marsh Funnel Viscometer uses a metal orifice in discharge tip to provide accurate readings continuously. Plastic material was selected to resist deforming from heat and ruggedness. Funnel meets API Code RP 29 specifications and plastic insulates hot muds from user's hands. *Baroid Division.*

Circle number (20) on reply card.

Packaged Field Compressors

Clark Bros. Packaged Field Compressors provide up to 1000 bhp while mounted on a single skid only 35 ft long, complete with radiator, scrubber and accessories. New heavy-duty VeePac Models are 2-cycle, turbocharged, integral gas-engine-driven compressors. Models TVM-10 rated 825 bhp and TVM-12 rated 1000 bhp at 600 rpm are suited to a variety of field applications. *Clark Bros. Company.*

Circle number (21) on reply card.

Petroleum Loading Arm

Continental-Emsco designed a spring-balanced loading arm to withstand heavy usage and rough treatment. An exclusive steel riser joint uses widely-spaced, heavy-duty bearing for taking larger loads. A variety of packing elements handle a wide range of fluids and can be replaced without removing arm from rack or disturbing bearings. A snubber spring absorbs upward thrust when arm returns to rest position. Six standard models come in either 3-in. or 4-in. sizes. *Continental-Emsco Company.*

Circle number (22) on reply card.

Mud Specific Gravity

Portable, pneumatically-actuated Densitometer continuously indicates specific gravity of flowing drilling mud. Densitometer Model 1005-OA gives accuracy within plus or minus 1% under fluid pressures to 150 psi and temperatures to 300 F. Instrument requires 0.1 cu ft per min of actuating air under 15 to 400 psi pressure. *Bell Corporation.*

Circle number (23) on reply card.

Hydraulic Valve Actuator

Hydraulic valve actuator operates only for few seconds needed to open or close valve and provides an automatic locking feature that holds gate or plug in any desired position almost indefinitely. Oil-Dyne produces complete unit, which includes motor, pump and coupling, integral reservoir, pressure switch, hand pump, gages, and any required safety devices. Miniaturization of components and total elimination of external valving permits fitting within overall valve dimensions on most applications. Actuators serve in direct or remote control. *Oil-Dyne, Inc.*

Circle number (24) on reply card.

HYCALOG

CONTINUING RESEARCH FOR LOWER COST DRILLING

2,931 is A LONG NUMBER THAT SAVES DRILLERS THOUSANDS OF DOLLARS

That's the number of our U. S. patent on V-Door diamond bits. Developed by our own researchers, they have piled up a long record of saving big money for drillers. For example:

$17,500 saved in South Louisiana . . . $12,000 saved in Texas . . . $7,500 saved in Wyoming . . . $9,000 saved in Alberta!

These are but a few actual cases taken from our files.

Using the HYCALOG-developed "Core and Bust" principle, V-Door bits stay on bottom for long runs, reduce number of round trips and keep making hole for an exceptionally long life. All this adds up to what you're looking for . . . *lower cost drilling.*

Ask your HYCALOG *rep to show you some actual performance records on* V-DOOR *Bits. He has a stack of them.*

HYCALOG, INC.

505 AERO DRIVE, SHREVEPORT, LOUISIANA.

OFFICES IN PRINCIPAL OIL PRODUCING AREAS

DIAMOND BITS • CORE BARRELS • WELL LOGGING • DIAMOND CORING • CORE ANALYSIS • POWER SWIVELS

Shallow Production

Titan's air lift for stripper wells from 300 to 1500 ft deep uses 21 cu ft air compressors controlled automatically by pressure regulators. Time clocks maintain a constant pressure reservoir of air and direct it to individual wells. Three compressors can operate a 10-well lease. Firm also designed an emulsion treater in three sizes—10 to 20 bbl, 20 to 40 bbl, and 40 to 80 bbl. Their circulating fluid heater transfers hot water under forced-circulation into well through piping alongside tubing. *Titan, Inc.*

Circle number (25) on reply card.

Rolled-Thread Sucker Rod

A high-strength sucker rod pin design incorporates rolled threads and undercut pin. Cold-working metal during manufacture rearranges steel fibers and grain to follow contour of this thread, intended to give a dense structure at pin's root. Undercut pin avoids run-out thread and improves elasticity to absorb alternating stresses of pump cycle. *S. M. Jones Company.*

Circle number (26) on reply card.

Heavy-Duty Power Winch

Newly designed power winch features torque transmission directly from gear spider to drum, which eliminates key-shearing. Winch hoists 20,000 lb and an oilbath lubricates entire unit. *Koenig Iron Works, Inc.*

Circle number (27) on reply card.

Dual Tension Tubing Head

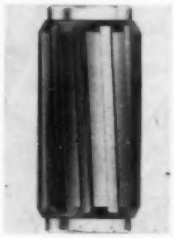
Oil Center Tool introduced a new dual tension tubing head that permits setting

parallel strings of tubing in controlled tension under blowout-preventer control. This DRT tubing head also permits manipulating and setting each tubing string independently. *Oil Center Tool Company.*

Circle number (28) on reply card.

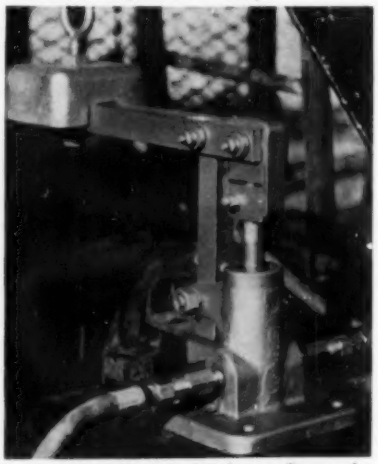
Thermoplastic Jacket On Sucker Rod Coupling

Liberty Manufacturing's Nyloglide sucker rod couplings have a special thermoplastic jacket molded securely over their outer diameter to reduce wear. Spiral flutes project from jacket without impeding fluid flow. Jackets are composed of a special nylon material containing fiberglass for added strength and a saturate of molybdenum disulphide for lubrication. Firm designed coupling to give mechanical advantages from reduced friction and resist corrosion and heat. *Liberty Manufacturing Company.*



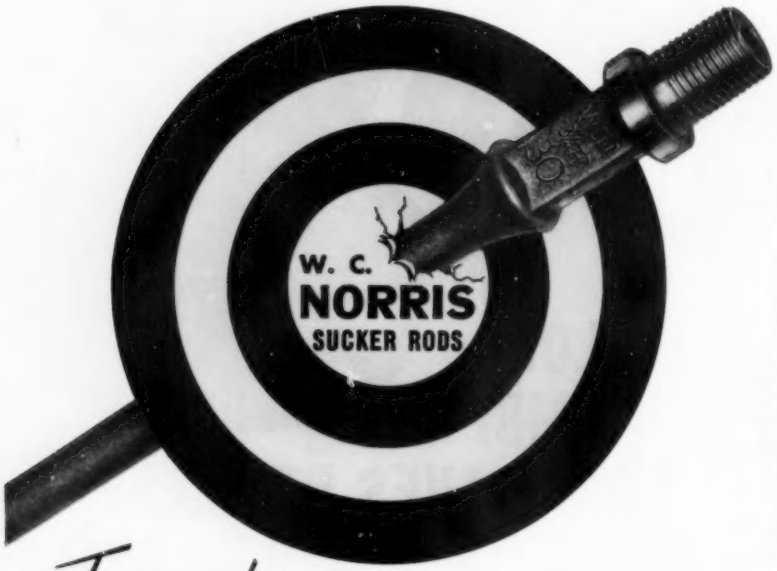
Circle number (29) on reply card.

Inhibitor Injection Pump



A simple Chemical Injector Pump delivers inhibiting solutions to either casing head or flow lines at a rate of from 5 gal to 150 gal daily against working pressures up to 1000 psi, manufacturer states. It strokes in unison with pump's walking beam through a chain or cable linkage. *Pacific Perforating Company, Inc.*

Circle number (30) on reply card.



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TYPE 78 Carbon-Chromium-Molybdenum Boron Alloy, normalized and tempered. For heavy duty pumping in non-corrosive or inhibited fluids.

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Replaceable Cone Bits

Both two or three-cone assemblies will fit into the same sub on DWV Replaceable Cone Bits. Machined compound taper locks shanks in place. Varel also developed DWV Replaceable Insert Blade Bits recently. *Varel Manufacturing Company.*

Circle number (31) on reply card.

Gas Compressor

Worthington designed CUB compressor for higher speeds up to 350 hp. Unit adapts particularly to gas gathering, gas lift, repressuring, and other field uses involving semi-portable compressor units of between 200 to 300 hp. This 5-in. stroke, 1000 rpm, 2-cylinder horizontal-opposed type unit couples directly to a high speed gas engine. *Worthington Corporation.*

Circle number (32) on reply card.

RUNNING TOUR — *Continued*

▸ **Exploration Logging, Inc.,** announced the formation of a new company, Exploration Logging Inc., S. A., for operation of all its services outside the United States. Ronald Ackley, will be executive vice president of the new subsidiary.

▸ **Geosonic Corporation** is the new name for Research Exploration, Inc., after its recapitalization resulting from a merger with Exploration Associates, Triton Drilling Company, Rex Drilling Company and Electronic Systems. The new firm will headquarter in Houston.

▸ **John H. Atwood** has joined Global Marine Exploration Company to represent the company in the Gulf Coast area. Atwood was most recently associated with Sohio Petroleum Company as superintendent of drilling operations, foreign and domestic.

▸ **W. P. Carver,** formerly with Mobil Oil Company as division land man-Western division, has joined the Great Basins Petroleum Company as vice president and director.

▸ Gulf Oil Corporation has named **R. D. Reedy** exploration manager for the Casper, Wyoming, area.

▸ **R. S. Grimes** has joined the production engineering division of Gulf Research and Development Company. He was formerly associated with Shell Oil Company.

▸ **John G. Yeager** has been named manager of the crude oil department of Humble Oil & Refining Company's Humble Division, succeeding **J. C. Posgate,** who was previously named manager of the Humble Midland area.

▸ A. M. Laurie and Robert W. Mannon have formed **Laurie & Mannon, Petroleum Consultants,** specializing in petroleum engineering and the evaluation of management of oil and gas properties. Both men are former employees of Gulf Oil Corporation in Los Angeles.

▸ **Holland R. Hunter,** an independent petroleum engineer from Houston, has been named chief engineer for the Mayflo Oil Company, Dallas. Mayflo operates primarily in the Anadarko Basin and has an exploration office in Midland.

▸ **R. L. Meadows** has been elected vice president in charge of operations for Movible Offshore Company, Houston.

▸ Namco International Inc., announces the appointment of **W. J. Harkey** as resident manager in Adelaide, South Australia, supervising a seismic exploration program Namco is conducting for Delhi Australian Petroleum Limited.

▸ **Thomas M. Curtis** has been named district superintendent for Pan American Petroleum Corporation's producing activities in Farmington, New Mexico.

▸ Shell Oil Company named **John C. Quilty** general manager of the personnel and industrial relations department.

▸ **William H. Wantuck** joined the engineering staff of Southern Natural Gas Company, Houston. He was formerly with Gulf Oil Corporation.

▸ **Steinhorst Operators' Service, Inc.,** petroleum engineer and management consultants, have extended their service to the Ark-La-Texas area. **R. D. Michaels** will represent the company in these areas, with office in Shreveport, Louisiana.

▸ **R. C. Mills Jr.,** was assigned to the position of assistant manager-N.O.J.V. interests in Houston for Standard Oil Company of Texas. **L. W. Funkhouser** is the new western division superintendent in Midland.

▸ Four appointments in Sunray Mid-Continent Oil Company's production department were noted: **G. D. Strother Jr.,** division engineer, Oklahoma City; **Myron Elliott,** district engineer, Oklahoma City; **R. K. McIntyre,** district office manager, Hobbs, New Mexico.

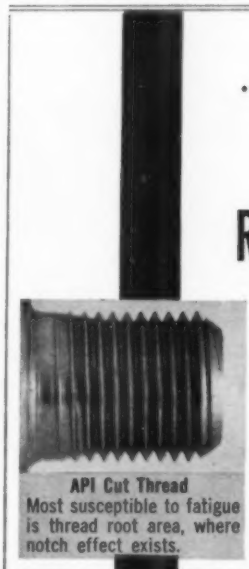
▸ Technical Drilling Service, Inc., of Midland has promoted **William E. Toombs** to vice president of the newly organized international division.

. . . another Jones First

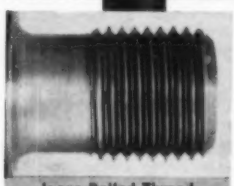
JONES

Rolled-Thread Undercut Pin

Greater Strength–Easier Make-Up



API Cut Thread
Most susceptible to fatigue is thread root area, where notch effect exists.



Jones Rolled Thread
Mirror-like surface aids application of make-up torque to pre-stress joint.

Rolled threads, made by cold working or displacing the metal into the thread form, are stronger at the very point where most cut-thread pin failures originate. Steel fibers and grain are rearranged to follow the thread contour, providing a dense structure at the critical thread root . . . added strength where it is needed most. Additional fatigue resistance is obtained by undercutting the pin shank, thereby eliminating the run-out thread and improving the elasticity of the joint. The superior finish and gauge tolerances attained in Jones rolled-thread sucker rod pins reduce friction and make possible greater prestressing of the joint with equal torque.

Ask your Jones representative for complete information on this new Jones development.

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JONES
SUCKER RODS

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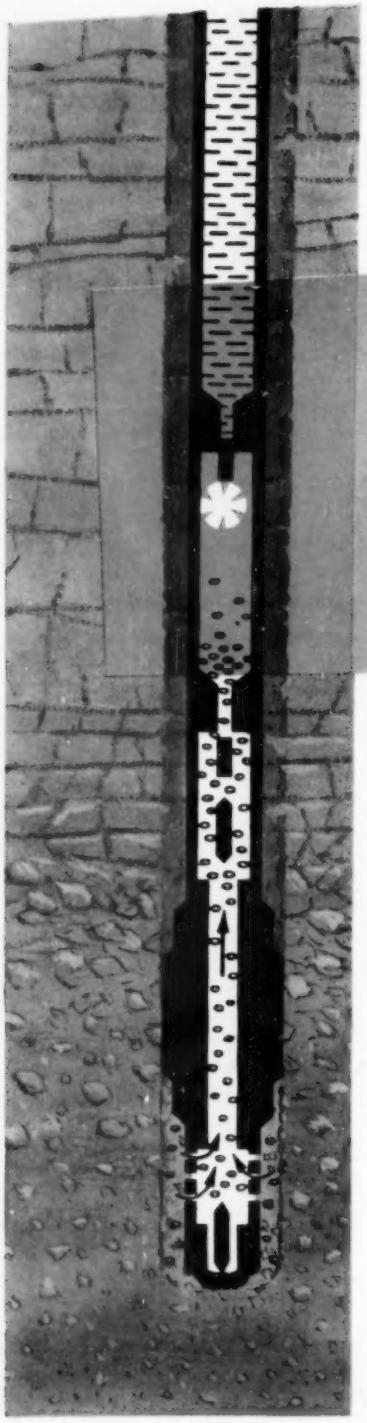
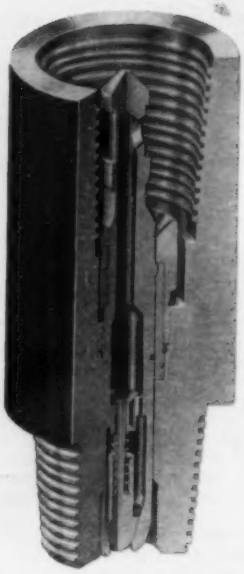


now! find low pressure payzones



. . . Regardless of Water Cushion

When testing deep formations, the hydrostatic pressure of the water cushion used to keep the pipe from collapsing can often hide potential production in a *low pressure* zone.

THE NEW HALLIBURTON RETRIEVABLE BACK PRESSURE VALVE can help avoid passing up these payzones by supporting the water cushion so its hydrostatic head does not affect the formation pressure recordings. The Back Pressure Valve is retrievable by wire line.

LOOK AT THESE RESULTS

On a recent West Texas test where the hydrostatic pressure of the water cushion used exceeded 900 psi, the use of the Back Pressure Valve allowed the operator to obtain the following formation pressure recordings from the zone tested:

Initial flow pressure	110 psi
Final flow pressure	303 psi
Closed-in pressure	566 psi

Since all formation pressures were less than the hydrostatic pressure of the water cushion, it is obvious that, without the use of the New Halliburton Back Pressure Valve, no formation pressure would have been indicated and this potentially productive zone might have gone undetected.

ASK YOUR HALLIBURTON TESTER ABOUT THIS NEW INNOVATION!

TESTING SERVICES

Another first in Formation Testing!

Halliburton
COMPANY • DUNCAN, OKLAHOMA

READY TO ROLL . . .

Another big tower for industry

Building and delivering big items like the 165-foot-long fractionating tower pictured here is routine performance at Sun Ship. Two towers, each weighing 135 tons and identical with that shown above, were constructed for a petrochemical plant for processing petroleum gases. They were shipped on 9 flatcars. Railroad officials said it was one of the largest shipments ever moved by rail. Because of its length the shipment had to travel a circuitous rail route.

Whether it's a massive fractionating tower or intricate equipment, your requirements will be met with exacting precision and your product delivered on schedule by rail or water from our tidewater plant.

Sun Ship's modern fabricating and engineering services put these advantages at your fingertips. For full information, call or write our Sales Engineering Department.

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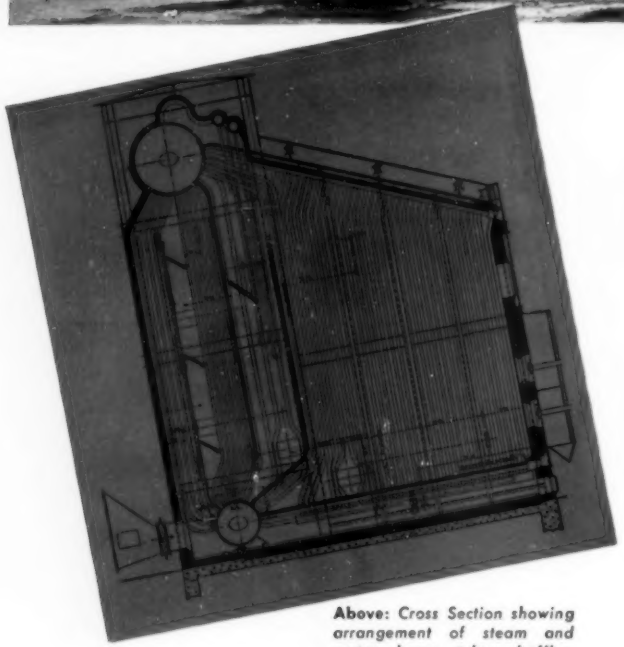
ON THE DELAWARE • SINCE 1916 • CHESTER, PA.

Vogt STEAM GENERATORS

at SUNTIDE REFINING COMPANY
Viola, Texas



Above: *Cross Section showing arrangement of steam and water drums, tubes, baffles, and furnace.*

6 EFFICIENT AND ECONOMICAL UNITS SERVE THIS MODERN REFINERY

Principle Data Each Unit

- 85,000 pounds steam per hour capacity, designed for 500 lbs. S.W.P. and 625° F. total temperature.
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Vogt offers a complete line of custom built and package type steam generators. Available in bent tube and straight tube designs for solid, liquid, or gaseous fuels burned singly or in combination.

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construction briefs

Construction contracts for the new Monochem, Inc. acetylene and vinyl chloride monomer plant at Geismar, Louisiana, have been awarded to Chemical Construction Corp., New York and United Engineers and Constructors Inc., Philadelphia. Cost will exceed $20,000,000. Monochem is a joint venture of Borden Co. and United States Rubber Co.

DuPont has announced plans to erect a multi-million-dollar methanol plant near Huron, Ohio, with capacity of about 30,000,000 gal annually. Construction hinges on approval by the Federal Power Commission of a pipeline extension to supply the plant with natural gas, which would be provided by Ohio Fuel Gas.

W. R. Grace & Co.'s polymer chemicals division has awarded Fluor Corp., Ltd. a multi-million-dollar contract to design facilities to increase capacity of Grace's 50,000,000-lb-per-year linear polyethylene plant at Baton Rouge, Louisiana.

A multi-million-dollar gas processing and sulfur plant will be built by Shell Oil Co. in the Bryans Mill gas field in Cass County, Texas. It will be designed to process 30 MMcf of gas a day and for daily production of 5700 bbl of condensate, 130 long tons of sulfur, and 18 MMcf of pipeline-quality residue gas.

Construction of new catalytic reforming facilities is major project planned in a modernization program at Phillips Petroleum Co.'s Great Falls, Montana, refinery.

Hercules Powder Co. will add a new multi-million-pound plant to produce hydroxyethylcellulose at its Hopewell, Virginia installation.

Shamrock Oil & Gas Corp. will build an ammonia plant with capacity of approximately 150 tons a day at site of the McKee refinery near Dumas, Texas.

Shell Oil Co. is adding a $1,000,000 asphalt products processing plant to its Martinez, California, refinery.

Lone Star Gas Co. will spend $850,000 for dehydration gas compression facilities at its Gordon gasoline plant in Palo Pinto County, Texas.

Yacimientos Petroliferos Fiscales has awarded contract for design and construction of a $15,000,000 refinery at San Lorenzo, Argentina, to Hydrocarbon Research, Inc. New York, and Minera Aluminé, Buenos Aires. Initial production capacity will be 8000 to 11,000 bbl per day of high-octane gasoline and 720 to 1200 bbl per day of benzene.

Condea Petrochemie-Gesellschaft MBH, owned 50-50 by Continental Oil Co. and Deutche Erdol AG, Hamburg, Germany, will build a multi-million-dollar petrochemical plant near Hamburg to produce 50,000 tons of industrial alcohols annually from petroleum.

A $51,000,000 nitrogenous fertilizer plant will be built at Visakhapatnam, India, by International Minerals & Chemicals Co. and California Chemical Co., both of the United States and Parry and Co., Madras. Plant will use naphtha from the Caltex refinery at Visakhapatnam to produce fertilizer with nitrogen content of 80,000 long tons a year.

United Arab Republic's General Petroleum Authority plans a $75,000,000 petrochemical complex near government refineries at Suez. Expected annual production would be 200,000 tons of nitrogenous fertilizers, 5000 tons of polyvinyl chloride, 28,000 tons of ethyl alcohol, 10,000 tons of synthetic rubber, 17,400 tons of glycerol, 3000 tons of polystyrene, 6000 tons of polyethylene, 5000 tons of pure benzene or 9000 tons of toluene, 28,000 tons of pure sulfur from Belayim crude, and 6000 tons of dodecylbenzene.

Soc. Tuniso-Italienne de Raffinage (STIR), Tunis, has announced plans to build an oil refinery with annual capacity of 20,000 bbl per day, expandable to 30,000 bbl per day. Plant probably will be located either at Bizerte or La Goulette. STIR is a joint enterprise of the Tunisian government and Ente Nazionale Idrocarburi.

A $17,000,000 petrochemical plant will be built near Rotterdam by Esso Nederland, affiliate of Standard Oil Co. (New Jersey). Plant will have capacity of 220,000 metric tons a year and will produce benzene, toluene, xylenes, and xylene-related products such as paraxylene. Design will be based on process developments by Esso Research & Engineering Co.

Uniao Fabril do Azoto, Lisbon, Portugal, has awarded contracts to M. W. Kellogg Co. and two affiliates to build petrochemical facilities at Barra a Barra near Lisbon. They will include 180-metric-tons-per-day ammonia plant, 40,500-tons-per-year urea plant, nitric acid, ammonium nitrate, and nitro-limestone plants.

French and Dutch affiliates of Badger Manufacturing Co. will design and construct a 10,000-tons-per-year specialty rubber plant near Strasbourg for Polymer Corp. (SAF), France, new subsidiary of Polymer Corp., Ltd. Sarnia, Ontario, Canada. Contract totals $12,000,000.

Imperial Chemical Industries (England) will spend $300,000,000 within the next 10 years for construction of several plants in Rotterdam to manufacture petrochemicals. Construction work on first plants is expected to begin in 1962.

Mitsui Polychemical Co., Ltd., a joint venture of Mitsui Petrochemical Co. and Du Pont, will build a plant at Otake in Hiroshima Prefecture to produce 24,500 tons of polyethylene annually.

Polymer Corp. will build a full-scale plant for manufacture of polybutadiene at Sarnia, Ontario, Canada, where the company now has a pilot plant in operation producing a variety of stereospecific polymers.

A $23,000,000 refining plant will be built at Matias de Galvea, Guatemala, for Repugua Oil Refining Co. by Brebe and Doremus Co. and Pona Engineers, both of Houston.

Shell Oil is planning a lubricating oil manufacturing plant with annual capacity of 80,000 tons to be located at Geelong, Australia.

Petrocarbon Developments Ltd. (England) has signed an agreement to supply Rumania with a $2,240,000 polystyrene plant.

WHAT REFINERS SHOULD EXPECT FROM ANTIKNOCK SUPPLIERS... NOW, AND IN THE FUTURE

Today's gasoline is a mixture of many hydrocarbons and it is also a blend of many important decisions on the part of the refiner.

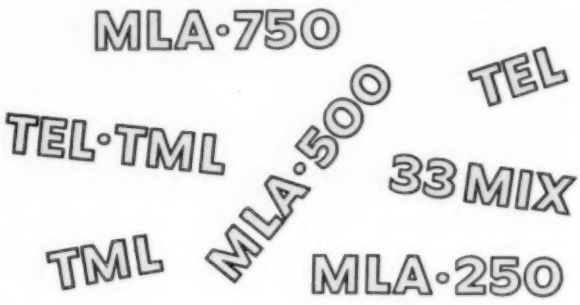
One important decision today is how to bring into agreement four factors—fuel composition, car population requirements, the best antiknock for a specific fuel and marketing objectives—to produce the most satisfactory and most profitable fuel.

The solution to the problem of matching fuel composition and antiknock is a complex one but, at the same time, one that can be rewarding in terms of better road performance at the same or less cost. Essentially it involves the optimum allocation of components and the blending of the right antiknock in the right concentration.

The selection of the antiknock is vital for it can contribute to the correction of an antiknock deficiency in a fuel, such as unsatisfactory motor octane and/or road performance, and at the same time reduce costs.

Changes in engine design and engine size are changing the octane requirement of the car population. Especially do foreign and compact cars have their own peculiar demands for fuel that will operate them satisfactorily at an economical cost.

Because there are so many factors that must be taken into consideration, the problem becomes quite complex. It is here that the antiknock supplier should be in a position to help in arriving at the best possible solution. That is why Ethyl is now even more actively engaged than ever in a program that will enable us to assist refiners in finding their own individual answers to: "Which antiknock—*exactly*."



No single antiknock enough

In prior years, changes in fuels and fuel-engine relationships were met satisfactorily by changes in the formulation of the one antiknock compound universally used by the oil industry.

Today, however, because the hydrocarbon composition of components varies from company to company—and even between refineries in a single company—no one antiknock can any longer be best for the whole industry or even for a single company. Therefore, to meet

ETHYL® ANTIKNOCK COMPOUND
ETHYL CORPORATION

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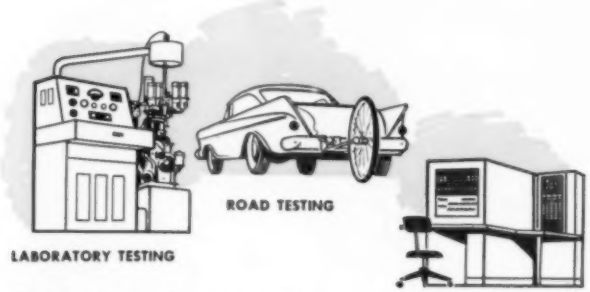
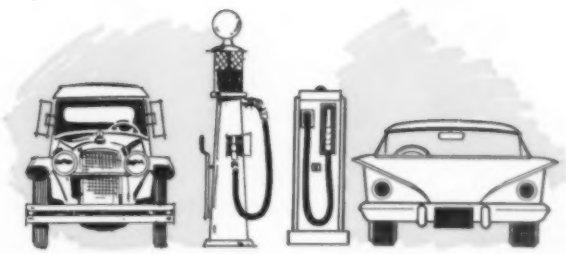
the industry's needs, Ethyl is now offering a number of antiknock compounds.



Ethyl takes action

To assist refiners in the selection of the antiknocks best suited to their needs, Ethyl has broadened its long-term program of matching fuels and antiknocks. A number of antiknocks, and combinations of antiknocks, are being tested in hundreds of gasoline blends from many refiners. These tests are for both laboratory and road rating and will be related to cost effectiveness. This project will produce a wealth of timely information for the individual refiner.

From this information it will be possible to make precise selection of an antiknock to insure optimum processing balance and minimum refining costs. In addition, an antiknock thus selected might well supply a refiner with an exclusive and promotable benefit that can be invaluable in the marketing function.



No substitute for experience

Long experience in the technology of antiknocks is necessary for the development of new antiknocks and their manufacture. Knowledge of the manufacture of one antiknock does not necessarily mean the knowledge required for the manufacture of another. While there may be surface similarities, there are often significant differences.

It is also experience that is the necessary ingredient in holding costs down. The successful, economical production of a finished product results from a complete know-how of the many processes involved and their economical operation.

Ethyl, with its 37 years' experience in this field, feels that it is especially suited to be of invaluable assistance to any refiner, regardless of size, who is facing the problem of; "Which antiknock for *us*!"

Ethyl Corporation

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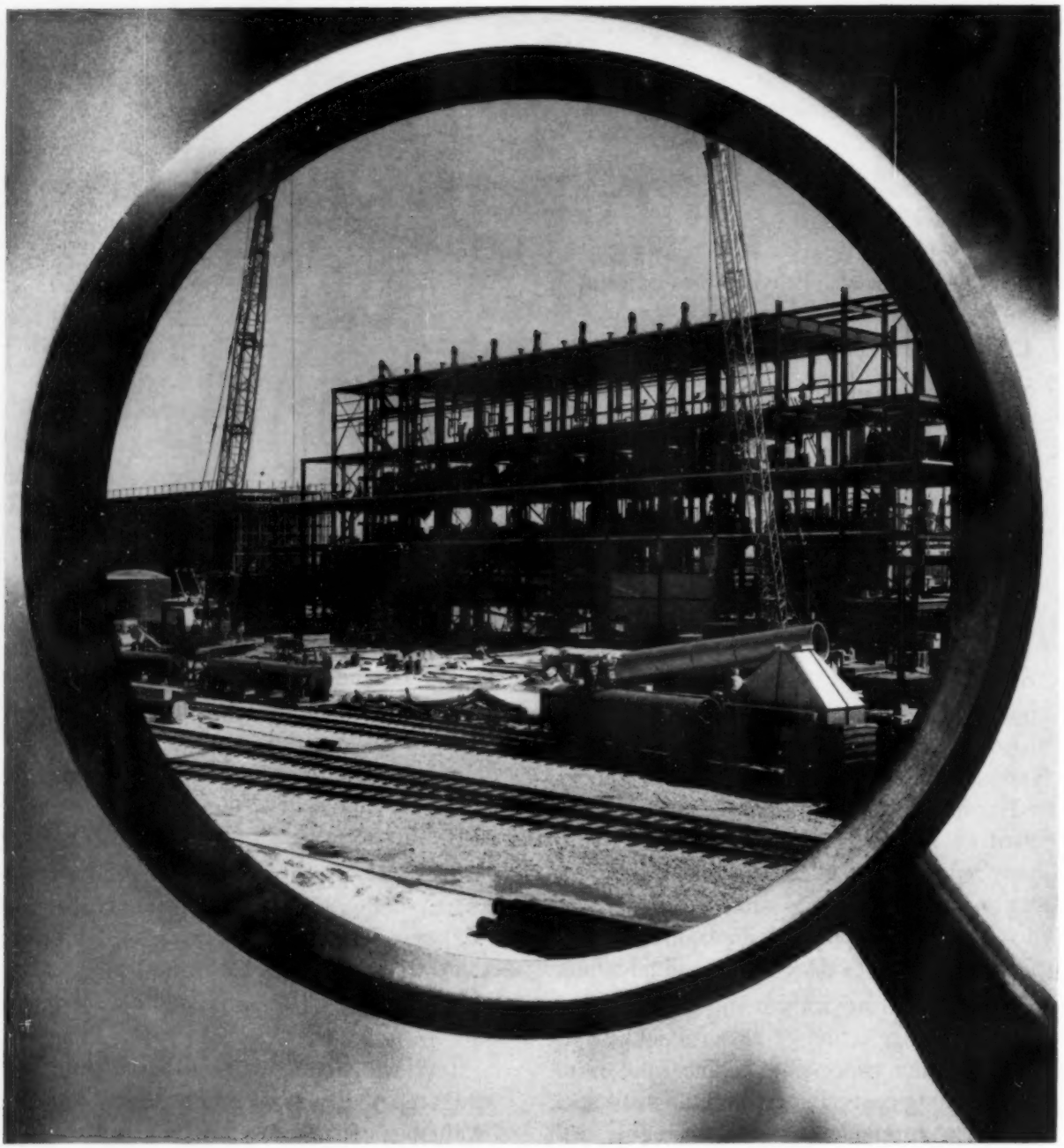

FLASH! Beaumont, Texas: Houston Chemical makes the news with its new, multimillion dollar gasoline-additive plant, set to go on stream here in July—way ahead of schedule. This plant's output of tetraethyl and tetramethyl lead will make Houston Chemical the country's third largest producer of these additives. Also included in the Beaumont petro-chemical complex will be an 80-million pound per year ethylene oxide plant—largest single unit of its kind ever constructed. This plant's glycol production will go into private label anti-freeze brands as well as bulk shipments. For further information, write Houston Chemical Corporation, 200 Madison Avenue, New York 16, New York.

HOUSTON

HOUSTON CHEMICAL CORPORATION

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standard or custom PRECIOUS METAL CATALYSTS for use in the organic and petroleum chemical industries

Engelhard PRECIOUS METAL CATALYSTS are available... on a wide variety of carriers ...in the form best suited for your needs... in the concentration most economical for your purpose

ENGELHARD'S MOST WIDELY USED SPECIES

	ALUMINA-SUPPORTED CATALYSTS
5%	Pt, Pd, or Rh on alumina powder
0.5%	Pt, Pd, Rh, or Ru on alumina pellets or spheres
0.3%	Pt on alumina pellets or spheres
	RD 150 or RD 150C

	CARBON-SUPPORTED CATALYSTS
5%	Pt or Pd on activated carbon powder
5%	Rh or Ru on activated carbon powder
0.2%	Pd on granular carbon

	OTHER CATALYST SPECIES
5%	Pd on $CaCO_3$ or $BaSO_4$ powder
	Pd or Pt oxide
	Pd or Pt black

For efficiency in promoting various laboratory chemical reactions and in large scale reactions including fabrication of rocket fuels, plastics and textile intermediates, high octane gasoline, heavy chemicals and fine pharmaceuticals, *consult with the Chemical Division of* ENGELHARD INDUSTRIES, INC. where *the world's largest research and production facilities* in the field of PRECIOUS METAL CATALYSTS are combined *to meet your requirements.*

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UNITIZED DESIGN

THE UNITIZED DESIGN OF WARNER LEWIS SPACE SAVER SEPARATOR/FILTERS provides the ultimate protection against water and solids contamination.

The proven superiority of Warner Lewis two-stage design is enhanced by the close correlation of over-all vessel design with details of element construction. The result: Unitized Design to achieve the highest performance standards — which are maintained only by the use of Warner Lewis factory engineered replacement cartridges.

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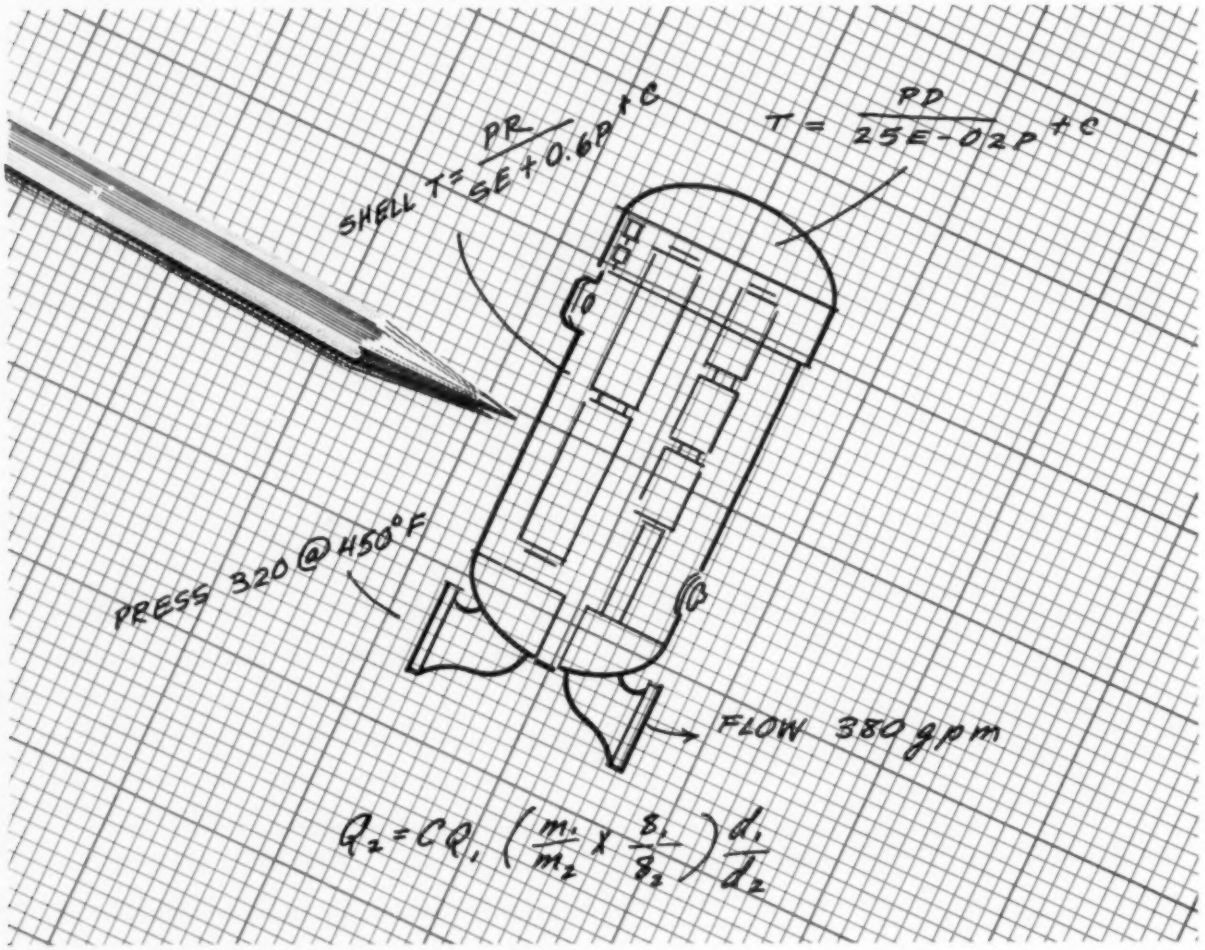

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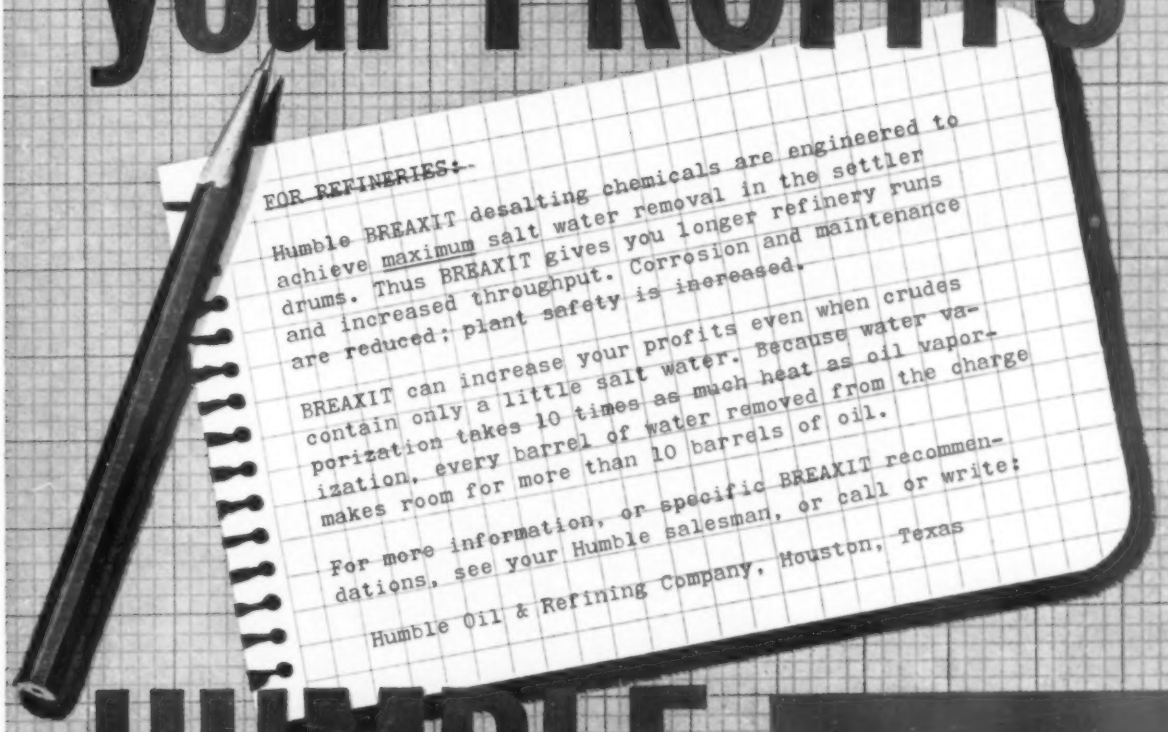
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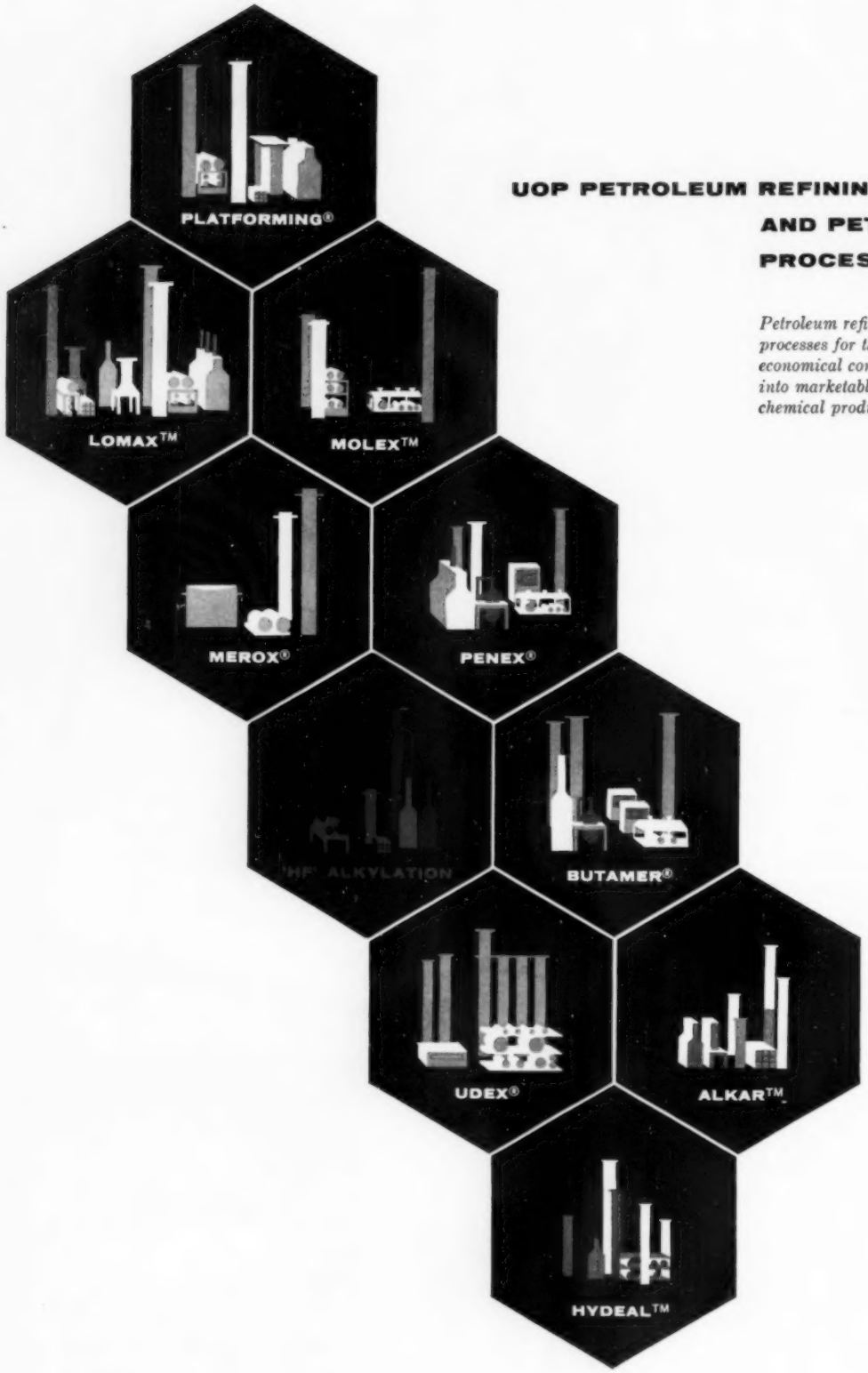

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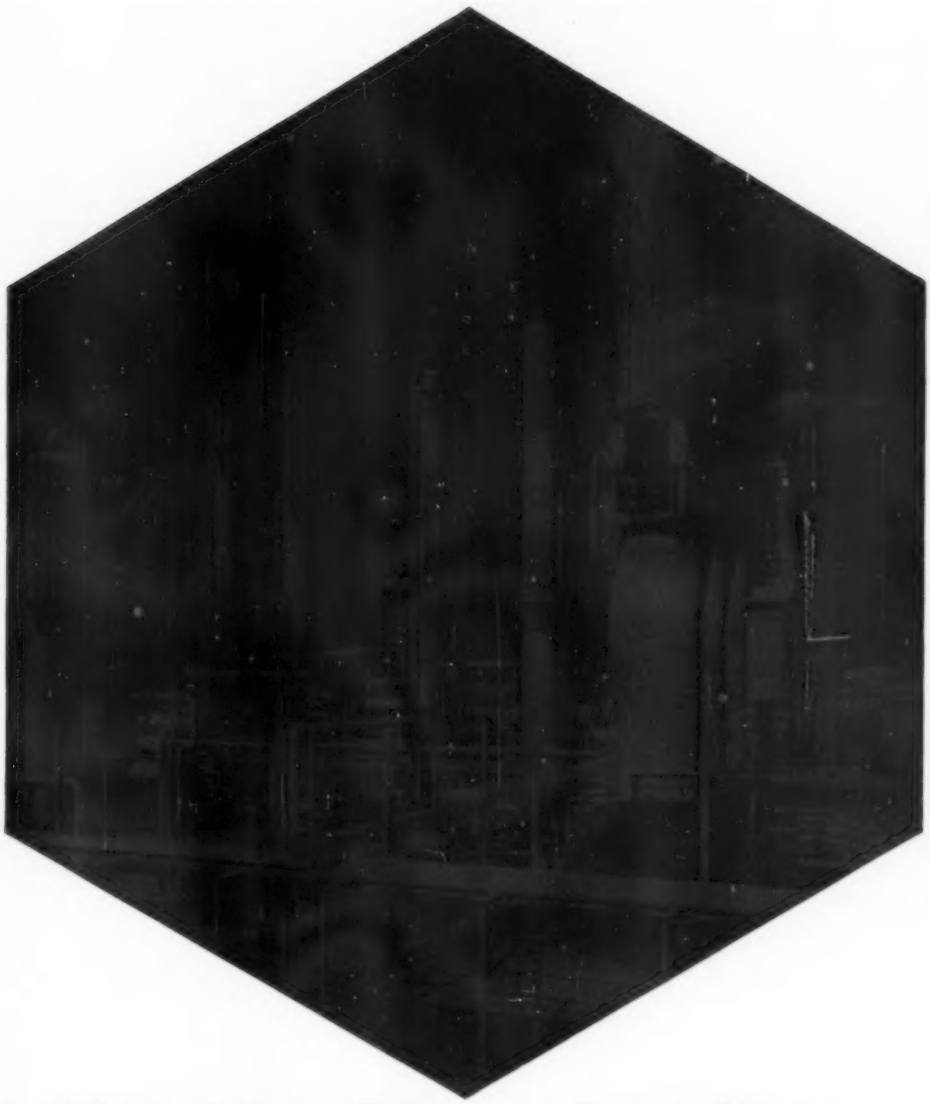

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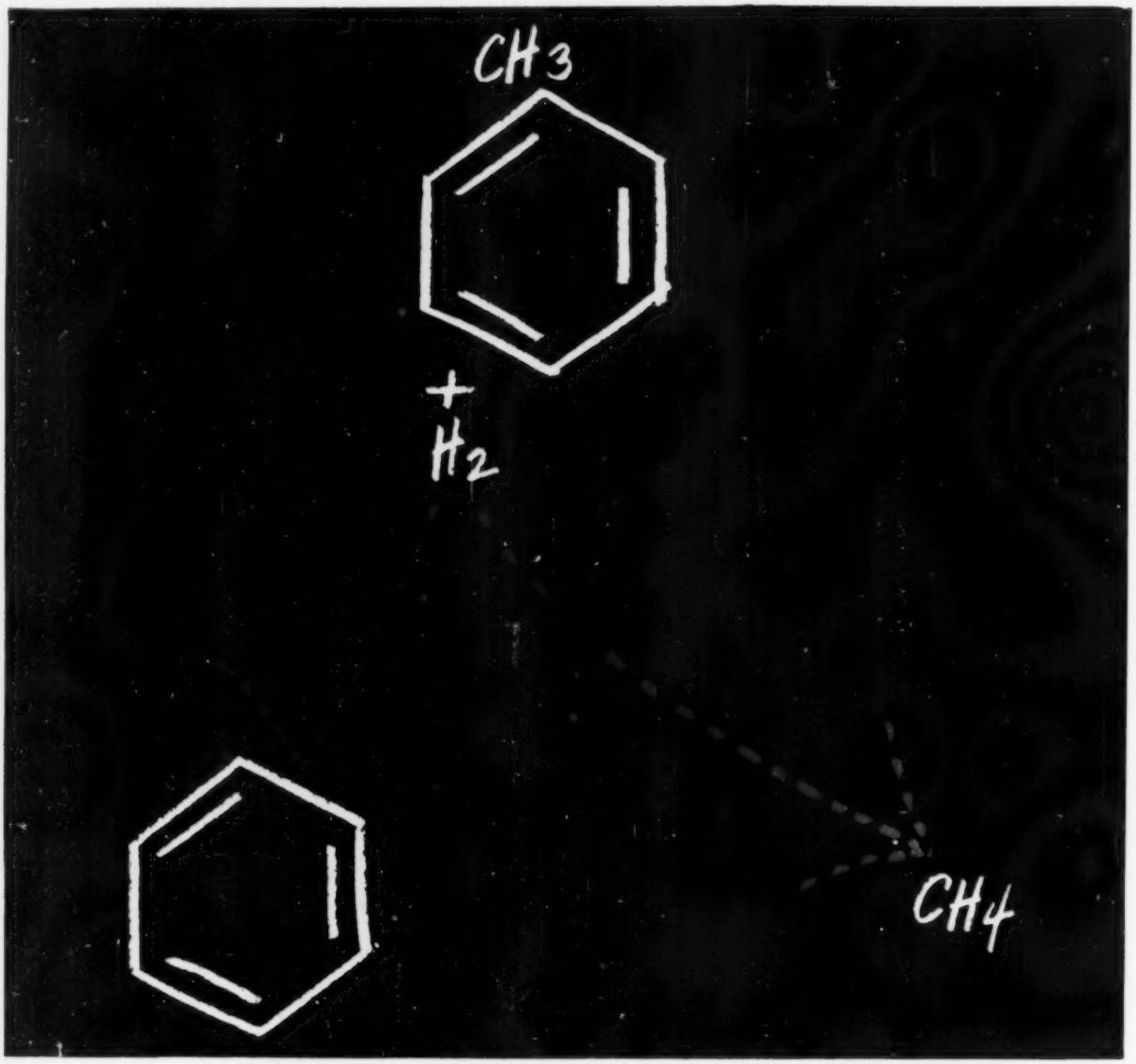

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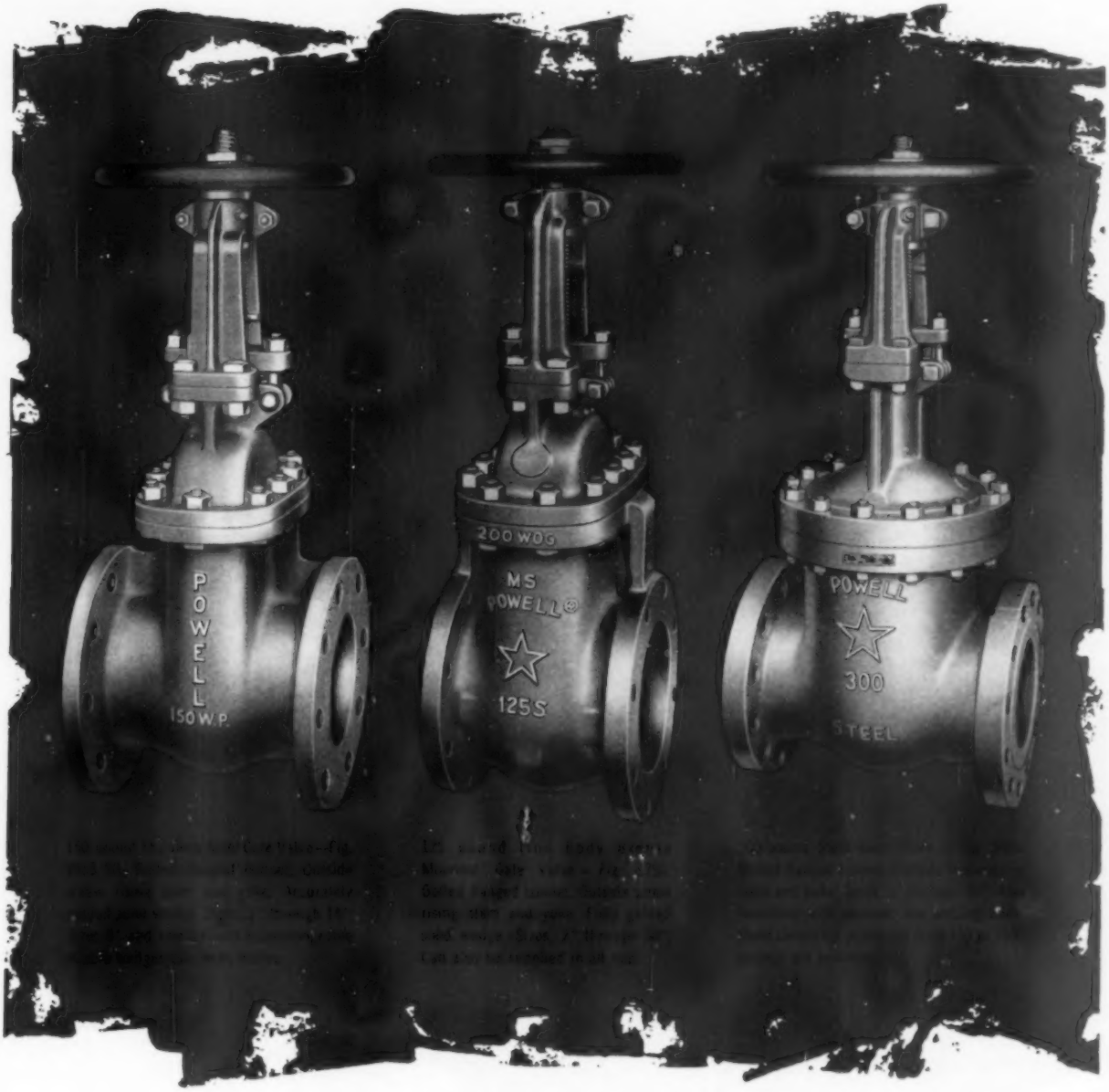

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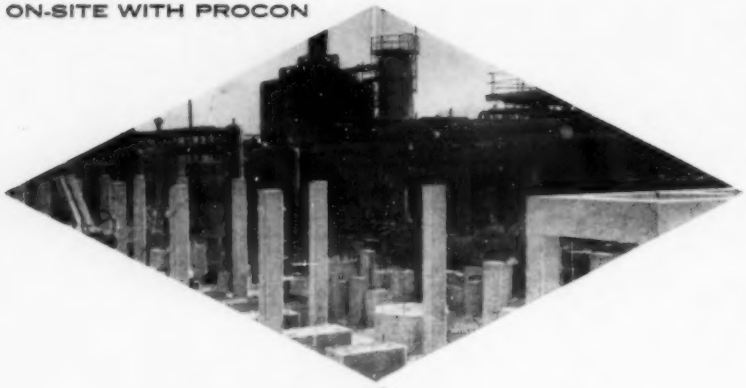

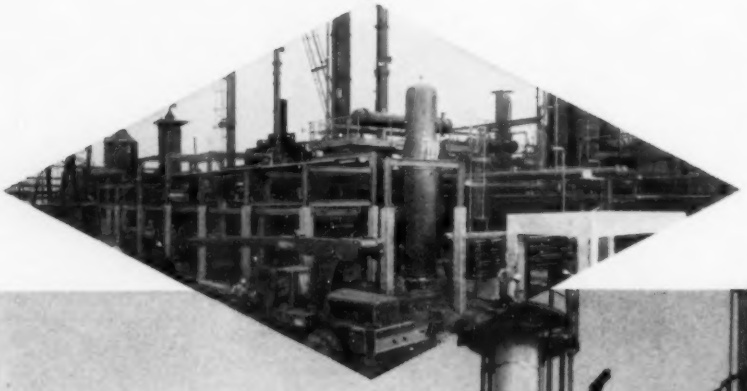

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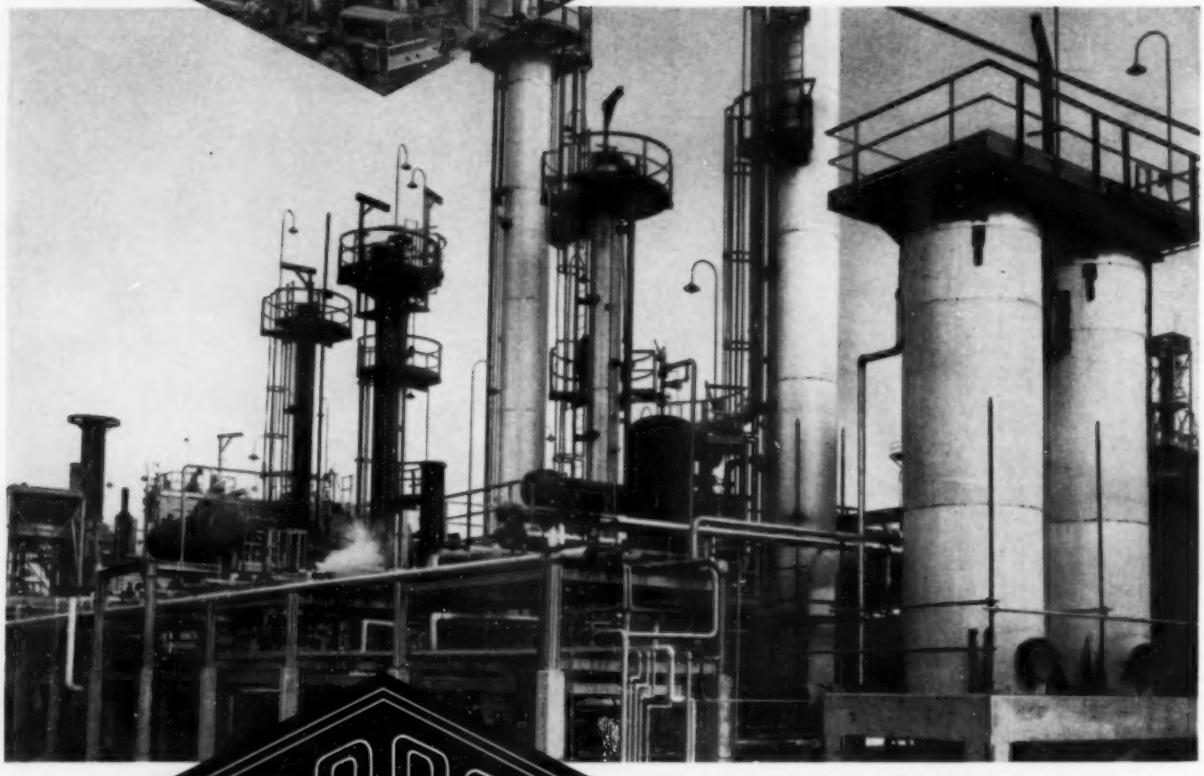

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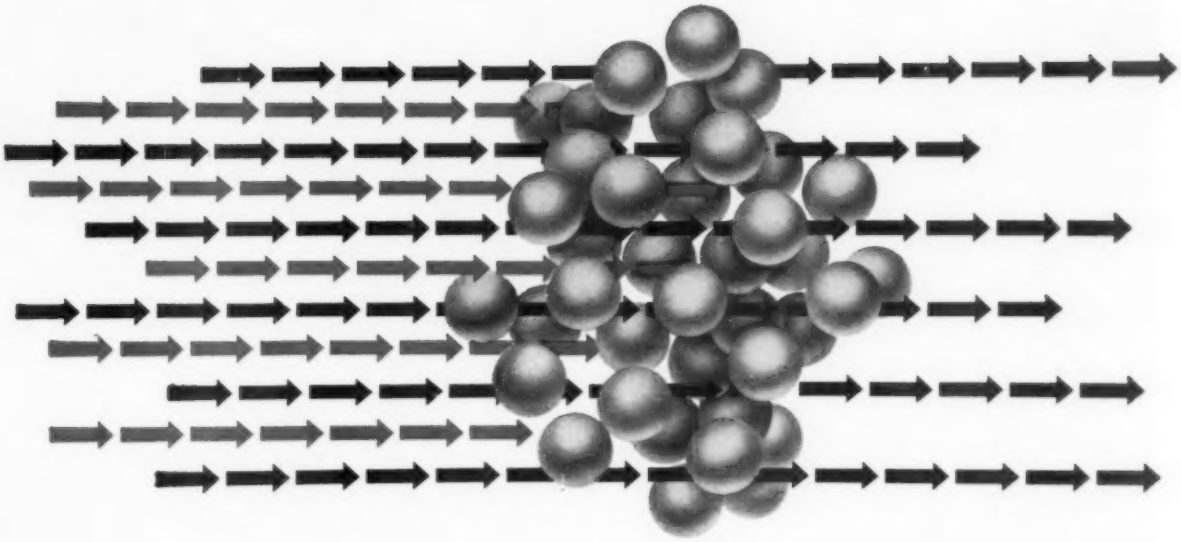

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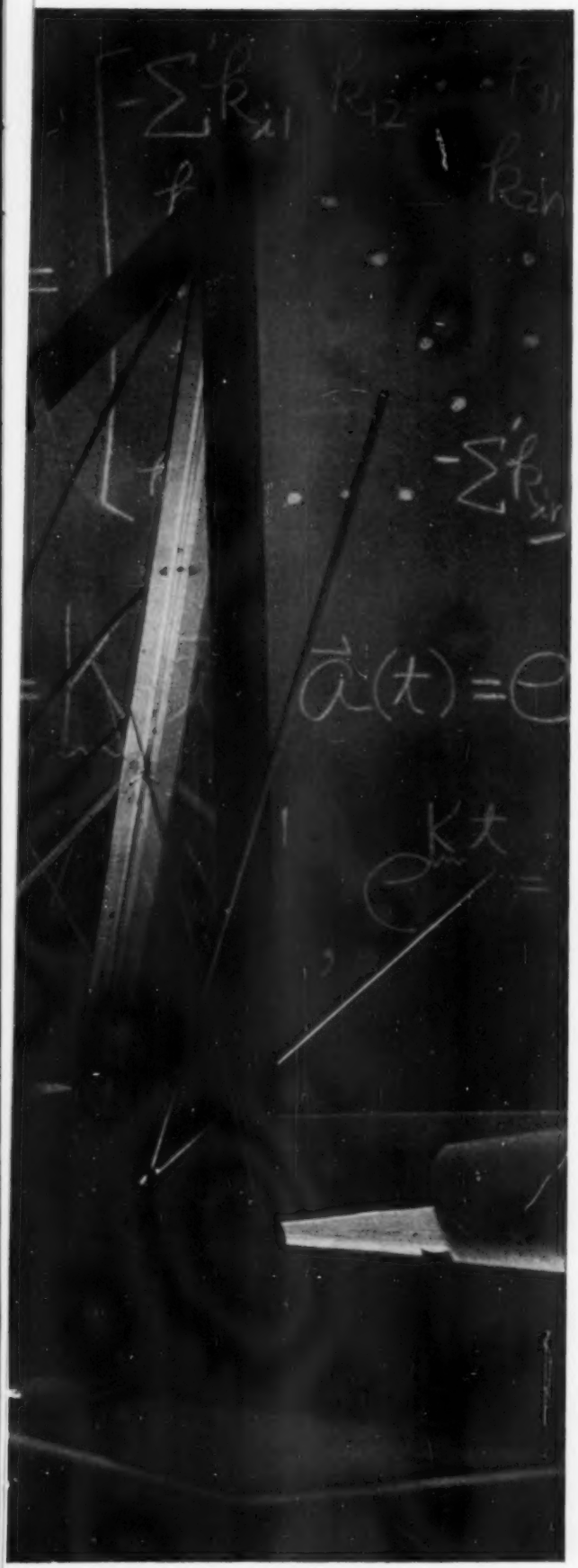
DWIGHT PRATER (seated) was born in Sylacauga, Alabama, in 1917. He holds a Ph.D. in biophysics from the University of Pennsylvania and has been a Mobil employee since 1951. An accomplished oboist, Dr. Prater manages the Haddonfield (N.J.) Symphony Orchestra.

JIM WEI was born in Macao, 30 years ago. He joined Mobil after receiving his doctorate in chemical engineering from M.I.T. in 1955. Dr. Wei is also a classical music enthusiast and plays piano for relaxation.



WHAT DOES A CHEMICAL REACTION LOOK LIKE?

A MATHEMATICAL MODEL of one is shown in this picture. The model represents a reaction that takes place in oil refineries every day.

Using an "off-beat" branch of mathematics, illustrated by this three-dimensional model, these Socony Mobil scientists have recently made an important breakthrough in the field of theoretical physics. They found a way to describe exactly what happens to petroleum molecules during refining. It formerly took hundreds of expensive laboratory experiments to get this information.

Their discovery allows Mobil to control chemical reactions with precision. As a result, we can now "freeze" refinery processes at exactly the proper stage to obtain maximum amounts of the products we want most. This means better products for Mobil customers.

These scientists have probed deeply and successfully into the foundations of petroleum reactions. The full implications of their breakthrough extend far beyond the specific problems of petroleum refining. Their work has given scientists everywhere greater insight and understanding into a fundamental process of nature.

Mobil encourages its scientists to give full play to their research interests and abilities. Dwight Prater points out that "our discovery was in a field in which neither one of us specialized at college."

Mobil scientists also are free to explore ideas which may appear to have little immediate application to the company's operations. Jim Wei notes, however, that "many of these investigations pay off handsomely later on—for the company and for us."

Dr. Prater and Dr. Wei are two of the 1,500 men and women engaged in Mobil's $25,000,000-a-year research program—in which imagination is turned into ideas, and ideas into better products and processes.

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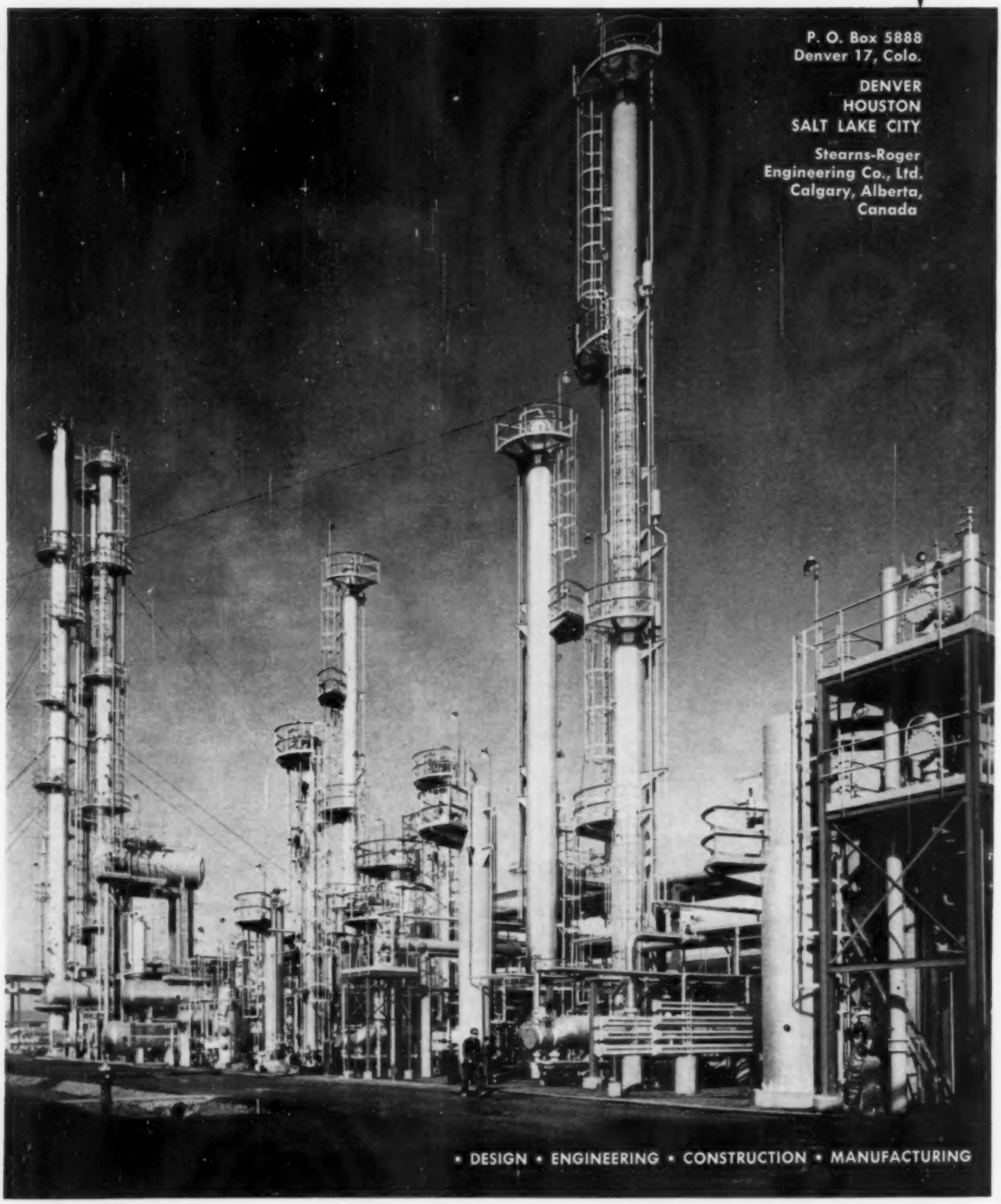

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Special Report—

CATALYTIC REFORMING

FRANK G. CIAPETTA
Director, Catalyst Research Department
W. R. Grace & Co.
Clarksville, Maryland

PETROLEUM TECHNOLOGISTS refer to the decade 1930 to 1940 as a major milestone in the application of chemistry and heterogeneous catalysis to the refining of petroleum. During this period much of the basic work was carried out in petroleum laboratories which forms the foundation of many of our modern refining processes. Extensive investigations of hydrocarbon reactions, in the presence of heterogeneous catalysts, soon showed the reactions of petroleum hydrocarbons could be carried out in a more selective manner to produce higher quality motor and aviation gasolines.

Development of catalytic cracking provided the refining industry with a process for producing higher yields of higher octane gasolines. Thermal cracking could not compete with this new process for converting gas oils into higher octane number gasolines. Conversion of refinery olefins such as butylenes and propylene to low boiling liquids by catalytic polymerization quickly replaced the brute force of high pressure and high temperatures for this reaction. The basic catalytic systems required for the alkylation of isoparaffins with olefins were developed during this period.

During this same decade catalytic petroleum scientists laid the ground work for development of the modern processes for the catalytic reforming of naphthas. They showed that certain catalysts, such as alumina supported chromia and molybdena, were sufficiently active and selective at high temperatures to catalyze reforming reactions of hydrocarbons which were of interest to the refining industry. This work culminated in 1939 in the construction of the first commercial catalytic reforming unit, which went on stream in 1940, and the subsequent units built prior to 1950.

At its inception, petroleum technologists were skeptical this new catalytic process would ever become an important refinery process. There was considerable justification for this feeling because by 1950 there was less than 80,000 bbl per day of installed catalytic reforming capacity. After World War II, the lack of demand for high octane aviation gasolines and the high cost of operating this process caused several refiners to discontinue using this process in their refinery scheme. In the four years following World War II, no new catalytic reforming units were built.

However, during the latter years of the 1940's every refiner suddenly realized a definite need existed for new reforming processes which could produce fuels of sufficiently high octane numbers, in economic yields, to meet the requirements of post war automobiles.

In 1943 a paper published in one of the petroleum journals[1] indicated petroleum catalytic scientists were investigating the catalytic properties of the active metal hydrogenation-dehydrogenation catalysts as possible constituents of

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THE AUTHOR

Dr. Frank G. Ciapetta is a leading authority on heterogeneous catalysis and application to chemical reactions.

Now director of the Catalyst Research Department of W. R. Grace & Co., whose Davison Chemical Division is the world's largest fluid cracking catalyst producer, Ciapetta has also been instrumental in development of key catalytic reforming processes for the Atlantic Refining Company and Socony Mobil Oil Company.

Ciapetta spent 12½ years with Atlantic in petroleum hydrocarbon chemistry and application of heterogeneous catalysis to this field. These investigations were directed toward discovery and development of new processes for the production of high octane motor and aviation gasoline.

His major contribution was discovery of a new general class of solid catalysts for the isomerization of hydrocarbons, which led to development of the Catforming process. Ciapetta holds the basic patents on this process.

He then worked 4½ years with Socony Mobil in development of very active platinum catalysts for the hydrocracking of gas oils to gasoline and also helped in development of the Sovaforming process.

Ciapetta holds 18 patents in the United States and has patents in 50 foreign countries. He is author or co-author of some 20 technical papers and contributed two chapters to a 6-volume series, *Catalysis*, published in 1957 by Reinhold.

naphtha reforming catalysts. It did not become obvious many petroleum technologists were also looking at these active metal containing catalysts until later in the 1940's.

These investigations led to the discovery of several new classes of hydrocarbon reforming catalysts which were more active and more selective than the supported metal oxide catalysts. These catalysts consisted of a metal such as platinum, palladium, nickel, etc., supported on an acidic oxide such as silica-alumina or a halogen activated alumina. It was found that by carefully balancing the activity of each of the components, the resulting dual function catalyst was an excellent naphtha reforming catalyst. These catalysts led to the development of low investment cost, fixed bed reforming processes, which would operate continuously for long periods of time before replacement of the catalyst was required.

Universal Oil Products Company in March 1949, announced the Platforming process. It was claimed this process could be used to upgrade straight run naphthas to high octane fuels, with small volumetric losses and with very attractive investment and operating costs. Within the next five years, nine new catalytic reforming processes were announced, clearly showing that parallel investigations on this refinery process were being carried out in many petroleum laboratories. Table 1 shows the chronology of the appearance of the various processes. A description of these processes may be found in the literature.[88]

Construction of new catalytic reforming capacity during the past 10 years has been phenomenal. The estimated installed capacity as of January 1, 1961, was nearly 2,000,000 bbl per day.[2] Of this total, about 95% is based on platinum containing catalysts, and the remainder on molybdena-alumina catalysts.

In the development of these new catalyst systems, a large amount of experimental work was carried out under simulated commercial reforming conditions, using pure hydrocarbons or mixtures of pure hydrocarbons as a feed stock. General availability of the mass spectrometer and other analytical tools permitted complete identification of most of the hydrocarbons in the products. In a number of cases, new dual function catalyst systems were developed primarily from studies in which mixtures of pure hydrocarbons were used as a feed.

As a result of these studies, a more complete understanding has been obtained of the role of each of the components in these catalysts, i.e., the hydrogenation-dehydrogenation component and the acidic oxide component, in the conversion of various types of hydrocarbons. These researches have led, not only to the development of commercial reforming catalysts, but also to the discovery of a number of new and unique catalyst systems for the selective isomerization of hydrocarbons.

Table 1. Catalytic Reforming Processes.

Process Name	Developed By	Date Process Announced
Fixed-Bed Hydroforming	Standard Oil Development Co.,[1] M. W. Kellogg Co. and Standard Oil Co. (Ind.)	1939
Platforming	Universal Oil Products Co.	Mar. 1949
Catforming	Atlantic Refining Co.	Feb. 1951
Houdriforming	Houdry Process Corp.	May 1951
Thermofor Catalytic Reforming	Socony-Vacuum Oil Co., Inc.[2]	May 1951
Fluid Hydroforming	Standard Oil Development Co.[1] and M. W. Kellogg Co.	May 1951
Hyperforming	Union Oil Co., of Calif.	Feb. 1952
Sinclair-Baker RD-150	Baker & Co. with Sinclair Refining Co.	May 1953
Orthoforming	M. W. Kellogg Co.	July 1953
Ultraforming	Standard Oil Co., (Indiana)	Nov. 1953
Sovaforming	Socony-Vacuum Oil Co., Inc.[2]	Jan. 1954
Rexforming	Universal Oil Products Co.	Mar. 1955
Iso-plus	Houdry Process Corp.	Mar. 1955
Powerforming	Esso Research and Engineering Co.	Mar. 1956

[1]Now Esso Research and Engineering Co.
[2]Now Socony Mobil Oil Co., Inc.

Development of naphtha reforming catalysts

The major constituents of petroleum naphthas are the paraffins, naphthenes, and aromatic hydrocarbons. It has been shown[56] the relative amounts of these hydrocarbons vary depending on the crude source. As shown in Table 2 the concentration of aromatics in reforming feed stocks is usually less than 20% of the total hydrocarbons present. The naphthene contents show a wide variation, from 12 to 70%, depending on the crude source. The naphthene fractions of these virgin feed stocks consist of a mixture of cyclopentanes and cyclohexanes. In some of these naphthas the concentration of cyclopentanes is higher than the cyclohexanes, but this depends on the source of the original crude.

From the standpoint of anti-knock quality, the most desirable constituents in high octane motor and aviation gasolines are the isoparaffins and aromatics. For example, aromatic hydrocarbons containing 7 to 10 carbon atoms have clear blending research octane numbers varying from 118 to 171.[57] The corresponding cyclohexanes have blending research octane numbers which vary from 43 up to 104.

The blending research octane numbers of paraffins also increase when going from a straight-chain paraffin to a branched-chain paraffin. For example, the research blending octane number of normal heptane is zero compared to 87 for 2,3-dimethylpentane.

Table 2. Naphthenes (and Aromatics) in Various Catalytic Reforming Feed Stocks.

	Boiling range, F	Weight % Naphthenes	Aromatics	Naphthenes & Aromatics
Arkansas		15.0	8.0	23.0
Pennsylvania		27.7	11.1	38.8
East Texas—Nat. Gaso.		20.0	6.0	26.0
East Texas		47.6	9.2	56.8
West Texas		38.7	20.8	59.5
West Texas—Mid. Cont.		44.0	9.0	53.0
Mid Continent		38.0	8.0	46.0
Gulf Coast		34.0	16.8	50.8
Gulf Coast		55.5	18.5	74.0
California		59.6	13.0	72.6
Seria, light	185-310	54.0	18.0	72.0
	310-384	51.0	31.0	82.0
Venezuela		43.0	22.9	65.9
Bachaquero	212-342	67.0	6.0	73.0
Merey	212-342	45.0	13.0	57.0
Tia Juana		46.0	10.0	56.0
Tucupido		32.5	28.0	60.5
Abqaiq, Saudi Arabia		12.0	16.0	28.0
Qatar	185-310	17.0	15.0	32.0
Kuwait		19.4	14.7	34.1

However, the octane number of equilibrium mixtures of the isomeric paraffins decreases with increasing carbon number. Therefore, the overall contribution of isoparaffins to the octane number becomes increasingly less as the molecular weight increases.

The direct production of aromatic hydrocarbons, during the reforming of straight run naphthas, includes dehydrogenation of cyclohexanes to the corresponding aromatics (Equation 1), and the dehydrocyclization of paraffins to aromatics (Equation 2). There are illustrated below:

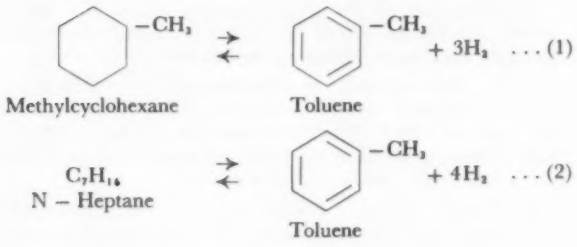
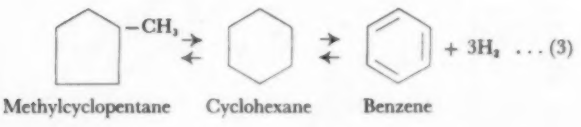


Fig. 1 shows the equilibrium concentration of toluene (in Equation 1) as a function of the reaction temperature (F), at various pressures.[58] The equilibrium data show that temperatures above 800 F are necessary, at pressures of 300 to 600 psig, to give conversion of 95% or higher of methylcyclohexane to toluene.

Calculated equilibrium data for the conversion of normal heptane to toluene and hydrogen are shown in Fig. 2, at various total and partial pressures of hydrogen. These data show that reaction temperatures above 850 to 900 F are necessary, at pressures of 250 to 500 psig, to obtain high yields of toluene. Varying the hydrogen/hydrocarbon mol ratio, at total hydrogen pressures of 250 to 600 psig, has only a relatively small affect on the equilibrium concentration of toluene.

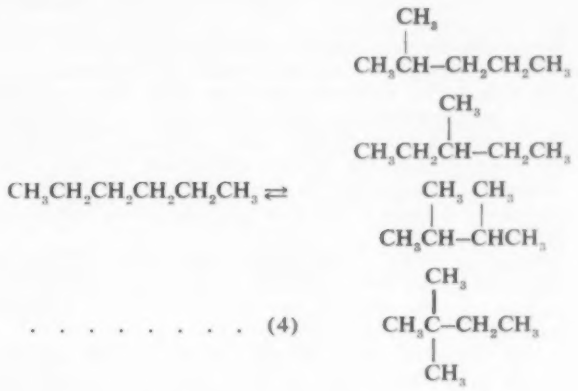
Since the naphthene portion of straight run naphthas contains large quantities of cyclopentanes, any reforming process depending on the above two reactions would not be able to produce high yields of high octane number reformates. To convert these cyclopentanes into aromatics it is first necessary to isomerize them into cyclohexanes. This dehydroisomerization reaction is illustrated in Equation 3.



If this reaction is carried out at high temperatures (750 F or higher), in the presence of a dehydrogenation catalyst, the cyclohexane will be dehydrogenated to form benzene. This reaction, dehydroisomerization of cyclopentanes to aromatics, is another of the important reactions required in the reforming of straight run naphthas.

Fig. 3 shows the concentrations of benzene in equilibrium with methylcyclopentane and cyclohexane, as a function of reaction temperature, at 175 and 500 psig pressure.[59] The thermodynamics of the system, methylcyclopentane-cyclohexane-benzene at these pressures, show that temperatures above 850 F are necessary to obtain yields of benzene above 90%.

As mentioned above, the isomerization of straight chain paraffins to branched chain paraffins is also a desirable reaction in the forming of naphthas. This reaction is illustrated below:



As indicated by Equation 4, normal hexane can isomerize to form four isomeric hexanes. The research (clear) blending octane numbers of the branched hexanes are between 83 and 96, compared to 19 for normal hexane. Hence it would be desirable to convert all the normal hexane to the branched hexanes. However, since an equilibrium mixture of all the isomers is obtained, complete conversion of normal hexane is not possible. Therefore, in the isomerization of normal

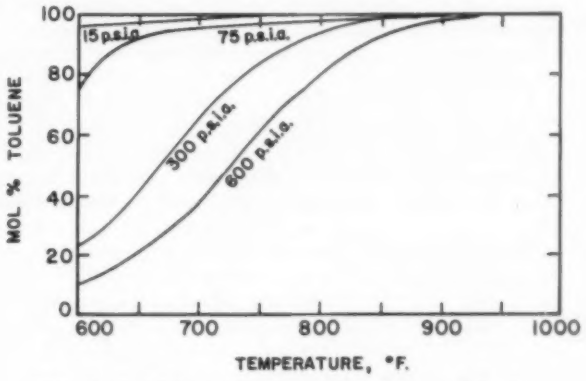


FIG. 1. Equilibrium distribution for system methylcyclohexane-toluene-hydrogen in the absence of added hydrogen.

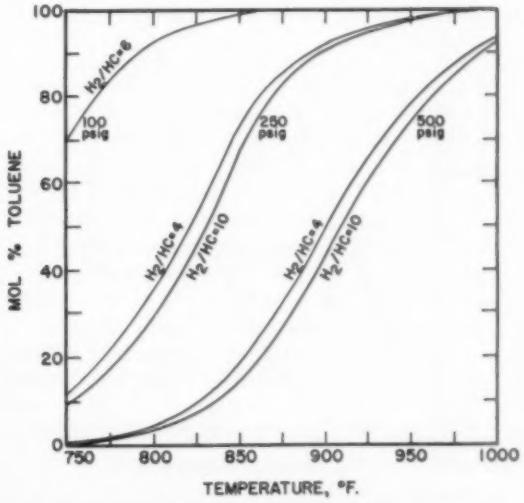


FIG. 2. Equilibrium distribution for the system n-heptane-toluene-hydrogen.

$$CH_3CHCH_2CH_2CH_2CHCH_3 + H_2 \rightarrow CH_3CHCH_2CH_3 + CH_3CHCH_3 \quad \ldots\ldots\ldots (5)$$

hexane, the blending research octane number of the product will be lower than that of the branched hexanes alone.

For the higher molecular weight paraffins, such as the C_8 to C_{12} hydrocarbons, the central hydrocracking of the molecule is also a desirable reforming reaction. For example, the hydrocracking of 2,6-dimethylheptane to form one molecule of isopentane plus one molecule of isobutane, shown in Equation 5, would increase the octane number of the reformate.

Although a certain amount of this central hydrocracking of higher molecular weight paraffins is permissible, it is necessary to limit the extent of this reaction in order to obtain high yields of reformate at high octane levels.

The extent to which isomerization of paraffins and the isomerization of paraffins plus central hydrocracking can increase the octane number of paraffins is illustrated by the data in Fig. 4.[58] However, the limits imposed by thermodynamics on the isomer distribution, place a relatively low ceiling on the octane number which can be obtained by isomerization alone. This is shown by the values in Fig. 5.[60] Nevertheless, the increase in octane number accompanying isomerization, together with the fact that paraffin isomerization involves small volumetric changes, makes this reaction a contributor to the over-all octane-yield.

There are a number of minor reactions which also occur in the catalytic reforming of straight run naphthas. These may include the following:

$$C_6H_{14} + H_2 \rightarrow CH_4 + C_5H_{12} \quad \ldots\ldots\ldots (6)$$

$$C_6H_{14} \rightleftarrows C_6H_{12} + H_2 \quad \ldots\ldots\ldots (7)$$

$$R\text{-}S\text{-}R + 2H_2 \rightarrow 2RH + H_2S \quad \ldots\ldots\ldots (8)$$

$$R_2NH + 2H_2 \rightarrow 2RH + NH_3 \quad \ldots\ldots\ldots (9)$$

Although the demethanation reaction (Equation 6) produces lower molecular weight paraffins, this reaction should be minimized to prevent hydrocarbon dilution of the recycle gas. Under normal reforming conditions, at pressures of 250 to 500 psig, the dehydrogenation of saturated hydrocarbons to olefins (Equation 7) occurs to a minor extent. In naphthas which contain sulfur or nitrogen compounds, desulphurization (Equation 8), and denitrogenation (Equation 9) occur to produce hydrogen sulfide and ammonia, respectively.

Consideration of the above reactions show that the requirements for an active and selective naphtha reforming catalysts may be summarized as follows:

1. It must contain a dehydrogenation-hydrogenation component which is active and stable at temperatures above 800 F. The concentration of this component should be controlled to minimize demethanation reactions.
2. It must contain an acidic hydrocarbon isomerization component which is active and selective at temperatures above 850 F. The acidity of the finished catalyst must be controlled to prevent excessive central hydrocracking of hydrocarbons.

Platinum Reforming Catalysts

As a result of the catalytic studies carried out during the past 30 years, we now know a highly selective reforming catalyst must contain a very active dehydrogenation catalyst. A number of experimental procedures have been used to determine the dehydrogenation activity of various metals and metal oxides.[61,62,63]

The data contained in Table 3 was obtained by measuring the rate of converting cyclohexane to benzene in a differential flow reactor under reforming conditions. The data show that chromia-alumina has one-sixth the activity of molybdenum-alumina. These results are in agreement with

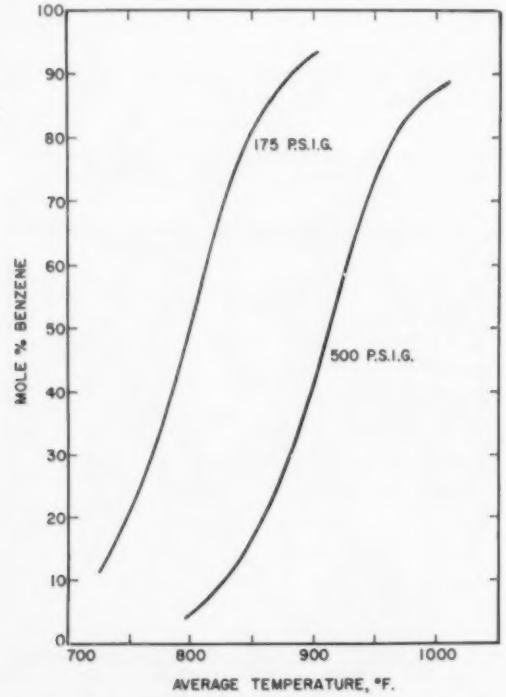


FIG. 3. Benzene-cyclohexane-methylcyclopentane equilibrium.

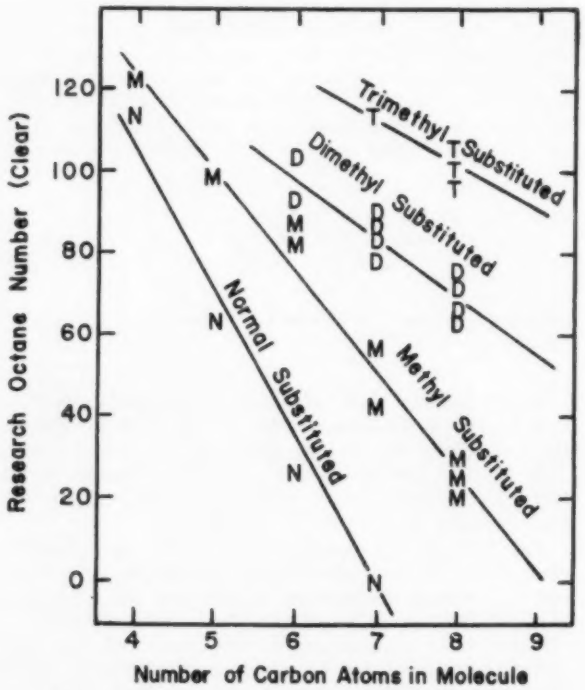


FIG. 4. Octane quality of paraffinic hydrocarbons. Ratings above 100 are blending values from 20% blends in 60-octane reference fuel.

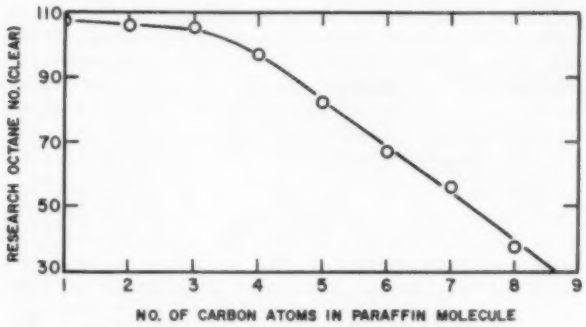


FIG. 5. Research octane number of 900 F. Equilibrium paraffin isomer mixture.

Table 3. Dehydrogenation Activity Values of Some Supported Metal and Oxide Catalysts.

Catalyst (wt. %)	Dehydrogenation Activity Index[a] (μ moles benzene/gm catalyst/sec)
34% Cr_2O_3 cogelled with Al_2O_3	0.5
10% MoO_3 coppt'd with Al_2O_3	3
5% Ni on Al_2O_3 or SiO_2-Al_2O_3	13
5% Co on Al_2O_3	13
0.5% Ir on Al_2O_3	190
1% Pd on Al_2O_3	200
5% Ni on SiO_2	320
1% Rh on Al_2O_3	890
0.5% Pt on Al_2O_3 or SiO_2-Al_2O_3	1400–4000

[a]Determined with cyclohexane in a differential flow reactor at 800F, 100 psig H_2/HC-6 (mol), after 30 min. pretreatment in flowing H_2 at the same conditions.

Table 4. Reforming of 50% N-Heptane-50% Cyclohexane Blend.

Catalyst: 0.4% Pt-SiO_2(500 m^2/g) Pressure: 350 psig		H_2/HC: 4 (Mol.) L.H.S.V.: 2 v/v/hr			
Temperature F	750	800	850	900	950
Conversion (mol. % chg.)					
N-Heptane	0	0	1	27	49
Cyclohexane	50	83	97	100	100
Yield (mol. % chg.)					
Isoheptanes	0	0	1.0	7	9
Benzene	44	78	94	96	96
Methylcyclopentane	—	1	2	4	4

Table 5. Reforming of 50% N-Heptane-50% Cyclohexane Blend.

Catalyst: 0.5% Pt-SiO_2-Al_2O_3 (420 m^2/g) Pressure: 350 psig.		H_2/HC: 4 (mol.) L.H.S.V.: 2 v/v/hr		
Temperature F	750	800	850	900
Conversion (mol. % chg.)				
N-Heptane	83	89	93	97
Cyclohexane	92	94	97	99
Yield (mol. % chg.)				
Isoheptanes	51	38	22	2.0
Benzene	6	24	51	89
Methylcyclopentane	68	50	24	8

Table 6. Isomerization of N-Heptane Over PT/SI/AL Catalysts.

Effect of Surface Area

Pt. Concn: 0.25 wt. % Pressure: 350 psig.		L.H.S.V.: 2.0 v/v/hr H_2/HC: 4 (mol.)			
Surface area m^2/g	420	320	225	110	43
Acidity (MG KOH/G)	8.4	7.8	6.1	3.7	1.3
Temp. F for 70% conversion	703	743	783	843	878
Isoheptanes (mol. % chg.)	56.4	50.5	54.0	50.5	46.0
Selectivity ISO/N	0.80	0.72	0.77	0.72	0.67

the order of activities determined previously by hydrogen-deuterium exchange studies.[61]

The supported metal catalysts have activities ranging up to several orders of magnitude higher than the oxides. These results clearly show why platinum has emerged as the most desirable dehydrogenation component of naphtha reforming catalysts.

If platinum is supported on a non-acidic support such as silica gel, the final catalyst has essentially only one function —a high dehydrogenation activity for the conversion of cyclohexanes to aromatics. This can be easily shown by reforming a pure hydrocarbon blend consisting of 50% normal heptane and 50% cyclohexane. The results for a catalyst consisting of 0.4% platinum on a high area silica gel are shown in Table 4.

Under typical reforming conditions, this catalyst shows a very high activity and selectivity for the conversion of cyclohexane to benzene. However, even at temperatures of 900 to 950 F, very little isomerization of the normal heptane to isoheptanes occurs. At the higher temperatures, a major portion of the reacted normal heptane is converted to lower molecular weight paraffins by demethanation.

However, if the platinum is deposited on a high area silica-alumina cracking catalyst, the resulting catalyst is also very active for the isomerization of paraffins.[64] This is due to the high acidity of the silica-alumina support. The results for a catalyst consisting of 0.5% platinum on silica-alumina are shown on Table 5.

At a temperature of 750 F, this catalyst has a high activity for the isomerization of normal heptane to iso-heptanes and cyclohexane to methylcyclopentane. As the reaction temperature is increased, however, excessive hydrocracking causes a decrease in isomer yield.

These results also show that the dehydrogenation activity of this catalyst is very high for the conversion of cyclohexane to benzene at temperatures of 850 to 900 F. The low yields of iso-heptanes at temperatures of 850 to 900 F show that this catalyst is not suitable for the reforming of naphthas. The acidity of the silica-alumina is too high to give the balanced reforming catalyst required for high yields of reformate at high octane numbers.

However, it has been found, that by decreasing the surface area (and hence the acidity) of the silica alumina support, it is possible to minimize the loss of isomers at reforming temperatures.[12] In this study n-heptane was used as the feed stock. The effect of surface area (and acidity) on iso-heptane yields is shown in Table 6. The acidity of the silica-alumina supports, was measured by a standard titration procedure.

These results show that by lowering the surface area, higher reaction temperatures are required to obtain the same conversion of normal heptane (70 mol % based on the charge). The data also show that the isomer selectivity is essentially unchanged even for the lowest area support, although the reaction temperature is 175 F higher.

Additionally the results show that in developing a commercial naphtha reforming catalyst, one of the major problems is the adjustment of the acidity of the support to obtain the proper balance among the main naphtha reforming reactions. If during use the acidity of the catalyst is decreased by contaminants in the feed, higher temperatures are required to obtain the same activity for isomerization reactions.

Other methods can be used to control the acidity of platinum-silica-alumina catalysts. For example, it is possible to add controlled amounts of basic metal oxides such as sodium or potassium oxides,[65] or by adding controlled amounts of alumina to high area silica gel.[66] The results

of this latter method on a platinum-silica catalyst is shown in Table 7.

The data show that the pure silica gel in combination with platinum has practically no activity for the isomerization of normal heptane at a reaction temperature of 800 F. At this temperature the platinum-silica gel catalyst has a high dehydrogenation activity. The addition of 1.1% alumina to the silica gel gives a platinum catalyst which shows a high activity for the conversion of normal heptane to iso-heptanes.

Although the conversion of cyclohexane increases, the yield of benzene is markedly decreased because a large portion of the cyclohexane is isomerized to methylcyclopentane. Increasing the alumina content to 2.4% gives a more active normal heptane conversion catalysts, which still shows a high selectivity for the isomerization to iso-heptanes. Thus it becomes possible to control the acidity of the silica support by determining the amount of added alumina necessary to give a balanced dual-function catalyst under the conditions used in the reforming of naphthas.

Table 7. Platinum-Silica Catalyst. Effect of Alumina Additions

Charge {50% N-Heptane, 50% Cyclohexane} Pressure: 350 p lg. L.H.S.V.: 2 v/v/hr
Catalysts: ≈0.2% Pt. on SiO_2(≈500 m^2/g) H_2/HC: 4 (mol.)

	Temperature: 800 F			
Wt. % Al_2O_3 added	0	1.1	2.4	7.2
Conversion (mol. % chg.)				
N-Heptane	2	69	84	87
Cyclohexane	80	92	94	94
Yield (mol. % chg.)				
Isoheptanes	3	46	44	35
Benzene	67	29	25	25
Methylcyclopentane	8	51	51	51

Table 8. Platinum-Alumina Catalysts. Effect of Chloride Additions.

Charge {50% N-Heptane, 50% Cyclohexane} Pressure: 350 psig. L.H.S.V.: 2 v/v/hr
Catalysts: 0.25% Pt on Al_2O_3 H_2/HC: 4 (mol.)

	Temperature: 800 F		
Wt. % chloride added	0.06	0.49	1.2
Conversion (mol. % chg.)			
N-Heptane	8.0	46.0	79.0
Cyclohexane	85.0	93.0	96.0
Mol. % chg.:			
Isoheptanes	6.0	33.0	46.5
Benzene	78.0	40.0	43.0
Methylcyclopentane	4.0	36.0	35.5

Table 9. Molybdena-Alumina Catalysts.

Charge {50% N-Heptane, 50% Cyclohexane} Pressure: 100 psig. L.H.S.V.: 1 v/v/hr H_2/HC: 6 (mol.)

Temperature F	800	850	900	950
Conversion (mol. % chg.)				
N-Heptane	42	64	84	94
Cyclohexane	87	98	99	100
Yield (mol. % chg.)				
Isoheptanes	23	25	17	4
Benzene	60	82	96	98
Methylcyclopentane	22	13	2	0

Table 10. Chromia-Alumina Catalyst.

Charge {50% N-Heptane, 50% Cyclohexane} Pressure: 100 psig. L.H.S.V.: 1 v/v/hr H_2/HC: 6

Temperature F	850	900	950	1000
Conversion (mol. % chg.)				
N-Heptane	5	12	41	82
Cyclohexane	35	67	92	100
Yield (mol. % chg.)				
Isoheptanes	3	8	13	11
Benzene	30	58	85	98
Methylcyclopentane	4	7	5	3

Most of the commercial platinum reforming catalysts used today, consist of platinum deposited on a halogen containing alumina support. The function of the halogen is to impart sufficient acidity to the alumina to catalyze the isomerization reactions. Although in some cases a platinum catalyst supported on an alumina base will show isomerization activity as well as dehydrogenation activity, the resulting catalyst usually has too low an activity for long life in a non-regenerative process.

The results in Table 8 show that at 800 F, catalysts containing less than .06 wt % chloride show a very low conversion of normal heptane to iso-heptanes and cyclohexane to methylcyclopentane. However, by the addition of 0.49% chloride the activity of the catalyst for the isomerization reactions is increased tremendously. A further increase in the chloride content to 1.2% increases the isomerization activity of the catalyst. However, the selectivity for the conversion of reacted normal heptane to iso-heptanes decreases due to the increase in hydrocracking reactions.

Thus it is possible, by controlling the concentration of halogen on the catalyst, to exercise positive control on the extent of the isomerization reactions as well as on the hydrocracking reactions. This method is used in commercial reforming processes, using platinum-alumina-halogen catalysts, to control the activity of the catalysts and, hence, to control the useful life of the catalysts.

Other reforming catalysts

The initial research work carried out in this field was primarily directed towards utilization of hydrogenation-dehydrogenation catalysts such as molybdenum and chromium oxides. The early experimental work carried out at atmospheric pressure had shown these catalysts are active and fairly selective for the reforming reactions of hydrocarbons boiling in the naphtha range. Although these catalysts lost activity as result of coke deposition, on regeneration in air they regained most of their original activity. It was also shown that these catalysts were potentially useful commercial catalysts systems because of their resistance to sulfur poisoning and their stability to frequent high temperature regeneration.

Table 9 shows data for the reforming of a 50-50 blend of cyclohexane and n-heptane over a typical molybdena-alumina catalyst.[62] Similar data for a chromia-alumina catalyst[62] are given in Table 10. These results show the molybdena-alumina catalyst is more active than the chromia-alumina at comparable temperatures. This is in agreement with the higher dehydrogenation activity of molybdena-alumina shown in Table 3.

These results also show the molybdena-alumina catalyst is more active and selective for the isomerization reactions at the lower temperatures. The yields of iso-heptanes and methylcyclopentane, obtained with molybdena-alumina, indicate that the catalyst processes a fairly high acidity. The poorer selectivity of the chromia-alumina catalyst for isomerization at low temperatures would be one of the limiting factors on its ability to produce high yields of high octane reformate. This is probably one of the main reasons why this catalyst is not used commercially at the present time.

Commercial catalysts and process variables

As mentioned in the introduction, about 95% of the present U.S. reforming capacity utilizes a platinum-containing catalyst. The following discussion on catalyst variables is therefore limited primarily to the factors which affect the activity, selectivity, and life of platinum catalysts. The second part of this section, on process variables, is also limited to platinum fixed-bed reforming units, although some of these variables are also applicable to the other reforming processes.

Catalyst composition.

Catalysts containing platinum for use in fixed-bed reformers are dual-function catalysts, the platinum supplying the dehydrogenation function and the support providing the acid function. The platinum concentrations in commercial catalysts vary from about 0.3 to 0.7%. It has been shown[67] that platinum concentrations higher than 0.5 to 0.7 do not increase the activity of the catalyst, and that concentrations of about 0.3% are suitable for some processes.[68] The platinum on a fresh catalyst is in a highly dispersed form.

It has been shown by hydrogen adsorption methods[67, 69] that the platinum crystal size on a fresh platinum-alumina catalyst is less than 10°A. This is supported by x-ray line broading studies,[67, 69] which show the crystal size is less than 50° A. The data in Table 11 show a comparison of the surface area and crystal size of the platinum in bulk platinum and alumina supported platinum catalysts.[69]

The results in Table 11 also show the change in surface area and crystal size of the supported platinum when heat treated to temperatures of 1202 F and 1382 F for various times. The hydrogen adsorption and x-ray results show that any loss in activity of the platinum supported catalyst is due to a substantial growth in platinum crystal size.[67] Loss in platinum activity during reforming, in the absence of feed contaminants or poisons, is usually due to the agglomeration of platinum.

As described above, the acid function of platinum reforming catalysts may be supplied by an acidic mixed oxide support, such as low area silica-alumina, or a halogen containing alumina support. In the former case the surface area of fresh silica-alumina cracking catalyst is reduced by high temperature steaming to the desired value.[12] In the latter case the halogen may be added during preparation, or by the direct addition of organic halogen compounds to the reformer feed.

Balancing of the metal (platinum) and acid (support) functions to obtain the most efficient reforming is very important, as outlined earlier in this article. Any serious alteration of this balance, as the result of poisons in the feed, or of operational upsets, must be avoided for maximum operating efficiency and catalyst life.

Despite their general similarities, exact compositions, and methods of manufacture of most commercial platinum catalysts are closely guarded company secrets. Many incorporate small variations designed to produce the optimum performance for their specific process. Catalyst costs are about $9 to $14 per lb for fresh catalysts including platinum. Three to five pounds of fresh catalyst per barrel of designed daily charge are usually required for most reforming units. The spent catalyst is usually returned to the manufacturer where the platinum is recovered, deposited on fresh support, and then returned to the user at a cost of about $4 per lb.

Life of catalyst.

The total useful life of a platinum catalyst depends on a number of factors. These include boiling range of the feed, composition of feed (presence of olefins in feed), presence of catalyst poisons in the feed, and severity of operation. The lives of regenerative catalysts will also depend on the stability of the catalyst to regeneration.

It has been reported that non-regenerative platinum-alumina-halogen catalysts have been used to process up to 250 bbl of feed per lb of catalyst before replacement. Some refiners have reported catalyst lives of 100 to 200 bbl per lb of catalyst while operating at reformate octane levels of 95 to 97 (F − 1 + 3 ml).[70] Platinum-alumina-halogen catalysts used in low pressure regenerative units have been reported to last through 200 to 275 regenerations (in excess of 100 bbl per lb of catalyst) before discarding.[71]

Catalyst lives in excess of 136 bbl per lb of catalyst have been reported for platinum-silica-alumina catalysts.[14]

However, since the catalyst life will depend on the particular refinery, each refiner must determine for himself when it is necessary to replace his catalyst. He of course realizes that the more barrels processed per pound of catalyst the lower his catalyst cost, but he also realizes this must be weighed against the declining yields which accompany catalyst aging.

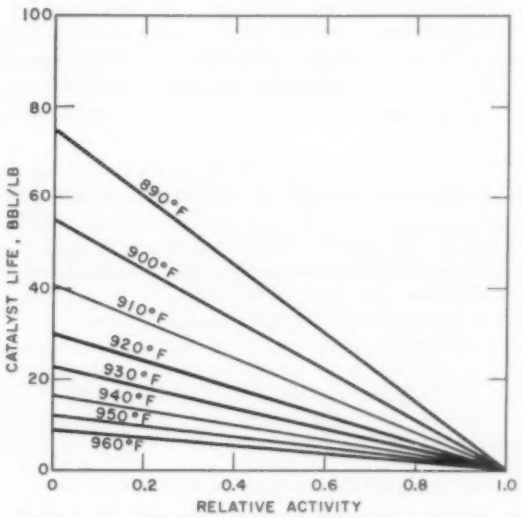


FIG. 6. Catalyst life vs relative activity at a space velocity of 2. Temperatures are that of the last reactor.

Table 11. Data on Platinum Dispersion.

Catalyst	Platinum S.A. (m^2/g)	Platinum crystal size (A°)	
		Adsorption	X-Rays
Pt Black	0.54	4300	
0.6% Pt on Al_2O_3 (Fresh)	273	<10	<50
0.6% Pt on Al_2O_3 (Heat treated 2 hrs at 1202 F)	38	61	200
4.46% Pt on Al_2O_3 (Heat treated 24 hrs at 1202 F)	11	212	255
3.10% Pt on Al_2O_3 (Heat treated 24 hrs at 1382 F)	9.2	253	255

A method has been outlined which provides the operator with a scientific method for calculating catalyst earnings for his reformer operation.[72] This procedure points out catalyst earnings depend on the average activity of the catalyst (which determines the life of the catalyst) and the change in over-all reformate yield with average activity of the catalyst (a selectivity factor).

The average activity is determined, at a fixed octane number level, by the temperature of the last reactor (using fresh catalyst) and the same temperature at any time during the run. This latter information, plus the change in catalyst selectivity with age, provides the basis for calculating the point of maximum earnings and hence the exact time for a change in catalyst.

For the Sinclair-Baker catalyst, the authors find the average activity, for constant quality products, is directly proportional to the life of the catalyst. However, poisons or other operational irregularities may change this relationship from a straight line. This relationship is shown in Fig. 6 at a 2-space velocity. The temperatures are those recorded in the last reactor.

Effect of boiling range of feeds on catalyst life.

Distillation ranges of reformer feeds are set by considerations of the final product desired and by the necessity for obtaining optimum catalyst life and maximum efficiency from the reforming unit. Most reformer feed stocks have an initial boiling point of at least 200 F. Materials boiling lower than this do not contribute greatly to increase octanes after reforming, and take up reformer capacity which can be more efficiently used by the higher boiling components more susceptible to large octane improvements.

Reformate end boiling points are normally about 15 to 25 deg higher than that of the charge, owing to the formation of higher molecular weight aromatics. As a result, end boiling points of reformer charges are limited to about 400 F or lower, in order to meet gasoline boiling point specifications.

In general, it is found that as the end point of the feed is increased, coke increases on the catalyst, resulting in a shorter catalyst life. This is true for platinum reformers operating at 500 psig in which regeneration of the catalyst is not practiced. Where the catalyst can be regenerated, this effect of higher end point of the feed, on the catalyst life, is not as serious as for the continuous operation.

Thus one of the advantages of the low pressure regenerative type operation is the ability to handle feed stocks with higher end points than can be used in the non-regenerative type platinum reforming. Frequently units not equipped for regeneration limit the end point of the charge to 375-380 F.

Effect of hydrocarbon composition of naphtha.

Straight-run naphthas provide the major feed stocks to platinum reforming processes. While any straight-run naphtha can be considered as a potential charge stock, the reformability over platinum catalyst will be governed by the hydrocarbon composition. This is true if the initial and end boiling points of the feed are similar. In the absence of any catalyst poisons, the average catalyst temperature required, other conditions being the same, will depend on the total naphthene plus aromatic content of the feed stock.

The data in Table 2 show that the naphthene plus aromatic content of feed stocks may vary from about 23% for Arkansas crude to as high as 67% for a Venezuela crude. The typical East or West Texas and Mid-Continent feed stocks normally vary between 50 and 60% naphthenes plus aromatics. Most of the reforming feed stocks from Middle East crudes usually vary between 28 and 34% naphthenes plus aromatics.

For a well balanced active reforming catalyst, the reaction temperature required to provide the same octane level reformate will depend on the total naphthene-aromatic content of the feed.

Therefore to reform a Kuwait feed stock to the same octane number as that obtained from an East or West Texas feed stock, it is necessary to increase the reaction temperature. As a result of the higher severity required for the Kuwait feed stock, it is expected that the total catalyst life, using this type of feed, would be lower than that using an East or West Texas feed stock.

Thus in a high pressure reforming operation using a non-regenerative catalyst, the life depends on the feed stock. Although the effect of feed composition is not as drastic for the regenerative type operation, the life of the catalyst will depend on the total number of times the catalyst can be regenerated before it is replaced.

The inclusion of unsaturated stocks, such as coker distillates, thermal or catalytically cracked gasolines, will have a profound affect on the life of the catalyst. In the absence of catalyst poisons, feed stocks containing unsaturated hydrocarbons will lay down more coke on the catalyst, resulting in a shorter catalyst life. It has been reported[68] that a feed stock containing 3 to 4% olefins caused the deactivation rate of the catalyst in the first reactor to increase approximately three times as high as during a similar period of time on virgin feed.

As pointed out below these stocks normally also contain catalyst poisons such as nitrogen and sulfur. These poisons cause an additional decrease in catalyst life if they are included in the reformer stock. There is general agreement among refiners that the pretreatment of reformer stocks containing unsaturated hydrocarbons is necessary in order to extend the life of the catalyst.

Effect of catalyst poisons on catalyst life.

In discussing catalyst poisons contained in reforming feed stocks, it is convenient to divide these into two classes: poisons which have a permanent affect on catalyst activity, and those poisons which have a temporary affect on catalyst life.

Metals such as arsenic, lead, and copper will permanently poison all platinum reforming catalysts. Sulphur and nitrogen compounds in the feed will also affect the activity and selectivity of all platinum catalysts. However, if these compounds are removed from the feed, an increase in activity is generally noticeable. Water and organic halogen compounds in the feed will effect the performance of all platinum-alumina-halogen. These contaminants can be considered to be temporary poisons if proper steps are taken to restore the catalyst to the desired acidity level.

Arsenic has a tremendous affinity for platinum. When this happens the activity ceases to exist and you no longer have a catalyst. Naphtha feed stocks with arsenic concentrations of four to seven parts per billion will definitely cause deactivation of platinum catalysts.[74] It has been reported that any time the concentration of arsenic on the catalyst exceeds 200 ppm in the first reactor there is a change in sensitivity of the catalyst which eventually kills the catalyst activity.[74]

As would be expected the first reactor removes the arsenic almost quantitatively. It has been found that the arsenic concentration on the catalyst decreases from top to bottom of the first reactor. When the arsenic concentration at the bottom of the catalyst begins to exceed 200 ppm there is apt to be a breakthrough of arsenic to the other reactors.

The removal of arsenic from naphtha reforming feed stocks is generally carried out by passing the feed stock through a pretreater before it enters the reforming unit. Some companies have used an acid treating step prior to

the reformer for the removal of arsenic.[74] In this process approximately ½ to 1 lb of sulfuric acid per bbl of charge is used. It is generally recommended that the arsenic content be less than one part per billion for long catalyst life.

Poisoning of platinum reforming catalyst by **lead** usually indicates the reformer feed stock has been contaminated either by picking up TEL from storage tanks, or by the inadvertent addition of Doctor's treating solution into the reformer feed. Although lead is considered to be a permanent poisoning, its affect on platinum catalyst does not seem to be as drastic as that of arsenic.

It has been reported that lead does not deposit in a band wise fashion as does arsenic. It frequently is found distributed unevenly throughout all three reactors and the highest concentration may be towards the lower part of the bed.[71] It has been reported that both pretreating the reformer feed or acid treating will remove the lead contamination from the feed stock.[74]

Mercury and **copper** are well known poisons for platinum catalysts. Hence, it is imperative that these poisons be removed from feed stocks prior to contacting the catalyst. Many refiners depend on their pretreater to remove these catalyst poisons as well as the poisons above in order to extend their catalyst life.

At the hydrogen-rich conditions employed in platinum reforming processes, **sulfur** containing compounds in the feed are readily converted to hydrogen sulfide. The hydrogen sulfide, unless removed will build up in the recycle gas system to an amount equal to two to three times its equivalent concentration in the feed. This compound is a reversible poison for platinum catalysts, and results in a decrease in the dehydrogenation and dehydrocyclization activities of the catalyst.

The affect of various sulfur compounds, at a feed concentration of 0.5% sulfur, on the dehydrogenation of cyclohexane and the isomerization of methylcyclopentane is shown in Table 12.[75] These results show the poisoning affect, on a relative percentage basis, is as pronounced for cyclohexane as for methylcyclopentane, and therefore must involve the dehydrogenation function of the catalyst. That relative percentage loss of conversion is no greater for methylcyclopentane than for cyclohexane would indicate that the isomerization function is little, if at all affected.

The presence of sulfur compounds in the reformer feed also affects the total life of the catalyst. Based on commercial experience of others it should be pointed out that hydrogen sulfide causes reforming catalysts to lose some activity permanently. This is evidenced by decreasing octane numbers at constant operating conditions.

Prolonged exposure to high partial pressures of hydrogen sulfide also affects the selectivity, resulting in a decrease of C_5^+ liquid product and an increase in C_4 and lighter materials. This effect on selectivity, at constant operating conditions, is shown in Fig. 7. The data are from a pilot plant study in which the feed stock contained a sulfur content of .01 and 0.17%.[76]

Although it is normally considered that sulfur is a temporary poisoning, it should be emphasized this is only true when sulfur compounds are present in the feed for a short period. Sulfur poisoning is cumulative and irreversible. A catalyst partially deactivated by exposure to a high sulfur stock will not regain full activity by switching to a low sulfur stock; however, further decline will be arrested.

It is frequently said there is an optimum concentration of sulfur compounds in the feed. This optimum has been placed at approximately 10 grains of hydrogen sulfide in the recycle gas to "take the edge" off of the extremely active fresh catalyst.[70] As the operation continues, the concentration is gradually dropped to a level of two grains by the end of the first three or four weeks.

It is claimed that if the sulfur is allowed to go above 10 grains, and maintained at this level, the yield of C_5^+ will decrease. Continuing levels of 20 to 30 grains are said to cause permanent damage to the catalyst. Other companies have stated that this optimum amount of sulfur is between 20 and 30 ppm in the feed. This means the amount of hydrogen sulfide in the recycle should be kept at a level of approximately .006% to .008% by volume.[73]

In commercial practice, sulfur is eliminated from catalytic reforming stocks by desulfurizing the feed by one of the many available commercial hydrotreating processes. Hydrogen sulfide is removed from the recycle gas by a chemical agent (such as diethylamine), whereby the sulfur in contact with the catalyst is limited to the sulfur concentration in the feed.

It has been consistently observed that **nitrogen** compounds such as ammonia or organic nitrogen compounds in the feed have an adverse affect on catalyst activity and product quality. Organic nitrogen compounds in the feed stocks are converted to ammonia under operating conditions. The ammonia reduces catalyst acidity, and thus represses isomerization, hydrocracking, and dehydrocyclization reactions.[66] More recent work has indicated that the dehydrogenation function may also be affected.[77] Any nitrogen compound, whether basic or not, in a reformer feed stock should be considered a temporary poison for all platinum catalysts.

There is general agreement among refiners that a total nitrogen content of 1 ppm is the maximum tolerable nitrogen content in reformer feed stocks. Many operators have reported[68] that when their feed stock contains about 1 ppm there is no noticeable effect on octane number of the product, or increased temperature requirements in the reac-

Table 12. Effect of Sulfur on Platinum Reforming Catalysts.

Wt. % Sulfur: 0.5%
Pressure: 300 psig
L.H.S.V.: 6 v/v/hr
H_2/HC: 4 Moles

	Methylcyclopentane			Cyclohexane		
	Aromatics in C_6 + (vol %)		Loss of Conversion %	Aromatics in C_6 + (vol %)		Loss of Conversion %
Sulfur Compound	No S in feed	S in feed		No S in feed	S in feed	
Hydrogen sulfide	40	26	35	86	53	38
Diethylsulfide	37	22	41	85	52	39
Phenyl mercaptan	36	21	42	87	48	45

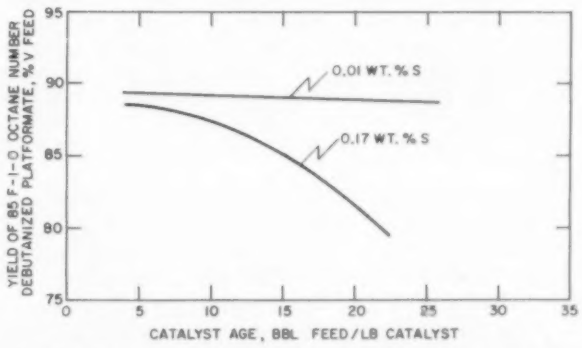


FIG. 7. Effect of sulfur concentration on Platforming yield of East-West Texas naphthas. Pressure 600-650 psig.

tors. Nitrogen contents above this figure require a definite increase in temperature in order to maintain the octane number at the required level.

Since the total life of the catalyst is determined by the maximum temperature in the final reactor, the presence of nitrogen compounds will diminish the total life of the catalyst.

Several methods of removing the nitrogen are being used at the present time. It has been reported that nitrogen compounds are removed by acid treating. One company reported that a feed stock containing 115 to 120 ppm total nitrogen after acid treatment showed a nitrogen content of about 2 ppm.[74] Refineries containing pretreating units usually have little difficulty in controlling the nitrogen level of their reformer feed stocks. A feed stock with approximately 15 ppm of basic nitrogen compounds was decreased to 1 ppm by passing through a pretreating unit.

There has been some question about the poisoning affect of **carbon monoxide** where flue gases are used as a means of starting a reforming unit, as a purge gas, or as a carrying medium for oxygen during the regeneration of catalyst. In the absence of hydrogen or oxygen, it is quite possible for the carbon monoxide to disproportionate on a hot platinum catalyst to carbon dioxide and carbon. Thus a decrease in catalyst activity could result from carbon lay down on the active platinum sites. Regeneration of the catalyst should restore its original activity.

Since a major portion of the reforming capacity uses an alumina-halogen support for the platinum, **water** and **chloride** in the feed must be considered as catalyst poisons. Platinum catalysts supported on silica-alumina supports are not affected by these two contaminants. To understand the affect of these two poisons on the activity and life of platinum-alumina-halogen catalyst, it is necessary to consider the action of each of these contaminants alone.

In the case of **water,** the principal poisoning affect of this contaminant is to decrease the acid function by leaching halogen from the catalyst. This destroys the balance between the acid and metal functions of the catalyst, and the isomerization and selective hydrocracking reactions are impaired. The required reforming severity for a given octane number becomes higher, and poorer yields and shorter catalyst life result.

In commercial practice, the charge may be prefractionated or dried to maintain water at the level of 5 to 10 ppm or lower. At this level in the feed, the recycle gas will contain roughly five to seven times this amount.[71] A number of companies have reported a definite advantage in yield by running a completely dried reformer feed and cycle gas to their unit. [68] This yield advantage is based on correction to a 10-lb vapor pressure basis. By taking out the last small amount of water, catalyst temperatures have been reported to drop by about 15 F at the same octane number reformate.

In those reforming units where the feed contains low concentrations of water (the order of 20 to 30 ppm), and facilities are not available for the dehydration of the cycle gas stream, the chloride level of the catalyst may be maintained through controlled additions of organic chlorides to the charge stock. The addition of 1.0 to 1.5 ppm of chloride to the feed for each 50 ppm water in the feed has been used.[68]

In platinum-alumina-chloride catalysts, the concentration of **chloride** in the finished catalyst controls the acidity of the catalyst. Hence the chloride content is a direct control of the isomerization of paraffins and cyclopentanes, and also selective hydrocracking of hydrocarbons.

If the chloride content in the catalyst is too low, or below the optimum amount, it will be necessary to use a higher average reactor temperature to get the same octane number. As a result the over-all useful life of a non-regenerative catalyst will be shortened, and the average over-all reformate yield may be decreased.

If the chloride content is too high, the rate of the hydrocracking reaction will increase, so that although the catalyst is very active for isomerization reactions, it will cause excessive formation of light gases and coke. Thus both the reformate yields and the life will suffer.

In those cases where the acidity of the catalyst has been reduced by chloride leaching, the operator can restore the catalyst to the proper efficiency by the controlled addition of chloride to the feed. Some companies prefer to use propylene dichloride or ethylene dichloride in various concentrations.[74] However, any organic chloride should suffice to deposit the necessary halogen required to restore the catalyst to the proper balance.

In the case of propylene dichloride, one company reported using about 600 cc per day when running 3000 bbl per day of feed stock. This rate gives about 2 to 3 ppm chloride in the charge which contained about 15 ppm of water. Other companies have recommended the addition of about 1 to 1.5 ppm of chloride for every 50 ppm of water present in the feed.[68]

In the case of ethylene dichloride, it has been reported that 0.025 to .033 wt % chloride in the feed, based on the weight of catalyst, is a satisfactory addition rate.[74]

Companies having Ultraformers have reported it is usually not necessary to add chloride during the run where the concentration of water in the feed does not exceed 15 ppm.[71] However, after regenerating the catalyst, sufficient chloride is added to the catalyst to bring the specific gravity of the recycle gas back to the same value obtained in the previous run. At this point the injection of chloride is stopped.

The first indication the chloride content of the catalyst is increasing is an apparent increase in the activity of the catalyst. For a non-regenerative catalyst, this increase in activity may cause the refiner to feel his catalyst costs will be decreased because the catalyst will last longer.

However, as soon as the chloride content exceeds the value necessary for proper balancing of the two catalytic functions of the catalyst, the loss in yield due to excessive cracking and the decrease in catalyst life will soon change his feeling of jubilation to one of despair. Unless something is done to restore the chloride content of the catalyst to the proper level, the total useful life of the catalyst may be shortened considerably.

It has been reported that reformate yields can drop as much as 3 to 5% in a few weeks, depending on the chloride level in the feed. In a 15,000-bbl-per-day reformer, losses of this magnitude can cost as much as $30,000 per month in loss product value.[78]

An increase in catalyst activity can be traced to the presence of organic chloride compounds in the feed. In many cases these organic chlorides are present in the feed because of the use of chlorinated solvents to dissolve and control paraffin wax deposition in oil well tubing and flow lines in many oil producing fields.[78] Some solvents for this service may contain from 30 to 40% of chlorinated hydrocarbons (trichloroethylene for example), while others have been as high as 90% (carbon tetrachloride for instance). These chlorinated hydrocarbons come back out of the wells with the crude oil and enter the complicated network of refinery operations where they have led to serious problems in catalytic reformers.

Although the amount of solvent being used for this purpose may seem small, the problem is aggravated because only selected fractions of the crude (in the range of 100 to 400 F) are catalytically reformed. Since the solvents used also boil in this region, they are concentrated many fold before charging to reformers.

It has been reported that crude oils containing these organic chlorides could easily contaminate 24,000 to 30,000 bbl of crude with sufficient organic chlorides to severely damage catalytic reforming operations and affect over-all refinery operations. For example, one company reported that apparently, as a result of obtaining crude oil which contained quite a bit of carbon tetrachloride, the chloride content of his reformer feed stock increased to about 16,000 ppm on the overhead of the stabilizer.[74]

As far as the operator is concerned, the most economical method of removing the organic chlorides in his reformer feed stock is to eliminate them from their source in crude oils. In the great majority of cases, this cannot be done simply by dilution of the contaminated crude, because of the extreme sensitivity of the reforming catalysts to chloride content of the reformer feed stock. Elimination of the use of chlorinated solvents at the oil field is the only sure way to prevent recurrence of this problem.

Organic compounds in the reformer feed can be removed by pretreating the feed. However, if the chloride content is high enough the operator should be prepared to experience serious corrosion problems in the stripper section and downstream in the gas plant and fuel gas systems, if the off-gas enters the refinery system.

In high pressure (400 to 600 psig) reforming units, the rate of **coke** deposition, in the absence of other contaminants, is one of the major factors determining the total life of the catalyst. Therefore, when using non-regenerative catalyst it is important to limit the end boiling point of the naphtha, and to eliminate any unsaturated hydrocarbons in the feed.

In this process coke is a permanent poison for the catalyst, and a continuous increase in reaction temperature is required to produce the same octane number reformate. Thus the total life of the catalyst is a function of the rate of coke deposition. When the reaction temperature gets too high for efficient reforming the catalyst must be discarded.

In those processes where a completely regenerable catalyst is used, coke is a temporary poison in the absence of other contaminants. After regeneration and adjustment of the acidity of the catalyst, the activity and selectivity of the catalyst is almost restored to its initial values. As mentioned previously, in regenerative reforming processes some catalyst have been regenerated well over 200 times.

The amount of coke deposited on the catalyst usually increases from the first reactor to the last. For example, in a high pressure 4-reactor unit, the amount of coke found was 1, 3, 5, and 6 to 8% respectively.[71] Another high pressure unit using a 3-reactor system, after 26 months of continuous operation, contained 9.8, 7.1, and 11.8%, in the first, second, and third reactors, respectively.[79] In low pressure regenerative units coke levels of 2, 5, and 14% respectively, have been found in the reactors.[71]

Several detailed discussions of the regeneration and the procedure used for the Baker-Sinclair 150 catalyst have been reported. [79, 80] In general, the unit is first depressurized and purged with an inert gas. After purging, the unit is pressurized with inert gas to 50 to 100 psig. Recycle inert gas circulation is then established through the normal system, the heaters are fired to 650 to 700 F, and air is admitted to each reactor inlet to initiate the regeneration.

At this temperature (750 F) the oxygen content of the regeneration gas is normally kept at 2% or lower in order to prevent excessive temperatures in the catalyst beds. After the main burn the catalyst temperature is raised to 900 to 950 F and the oxygen concentration increased to 15 to 18%. The final carbon level on the catalyst was found to be less than 0.2 wt %.

Effect of process variables

Temperature, pressure, space velocity, and hydrogen recycle rate are the principal operating variables in fixed-bed catalytic reforming.

Temperature increases are most effective in increasing the octane number of the products by increasing both the dehydrocyclization and central hydrocracking reactions. In general, reactor temperatures range from about 850 to 975 F. Temperatures higher than 975 F cause serious losses in product yields due to excessive hydrocracking, and in very severe cases, thermal cracking in the preheaters, particularly at low space velocities. In practice, the affects of declining catalyst activity with time on stream are compensated for by gradually increasing the operating temperatures up to the limits described above.

In high pressure reforming units, it is desirable to maintain the average catalyst temperature the same in each of the reactors in order to increase the catalyst life, and to obtain the maximum yield at a fixed octane reformate.[70] If the inlet temperature to each reactor is the same, then the average temperature of the catalyst will increase from the first reactor to the last reactor. This is due to the lower temperature drop in the second and third reactors. Since higher temperatures promote hydrocracking as well as increase coke deposition on the catalyst, both the life of the catalyst and the yield of products will decrease.

Space velocity and temperature should be interchangeable over the normal reforming temperature range of 850 to 975 F. Frequently the space velocity can be used to control reforming severity. Low space velocities increase hydrocracking (at constant temperature) but have little effect on the dehydrogenation of cyclohexanes to aromatics, since this reaction is quite rapid under normal operating conditions with platinum catalyst. Higher space velocities tend to inhibit hydrocracking. However, at the higher reaction temperatures, the catalyst may be deactivated faster, resulting in a more rapid decrease in yields at the same octane number reformate. In most processes, space velocities range from two to three liquid hourly space velocity.

Effects of the **reactor pressure** have been extensively discussed in the literature. [25,81,82] Upper limits of pressure, for high severity reforming, are limited by the effects of the required temperatures on the hydrocracking and thermal cracking of the feed stocks. Intermediate range (400 to 600 lb) reforming results in balanced operation, ideal for non-regenerative or intermittent regeneration processes.

Low pressure operation, on the other hand, represses hydrocracking and significantly increases the amount of aromatics formed. Higher gasoline yields are obtained and the hydrogen production is maximized. However, coking of the catalyst is increased due to the lower hydrogen partial pressure. The processes which employ low pressures (200 to 300 psig) are equipped with facilities for regular regeneration of the deactivated catalyst.[24,25]

The **hydrogen recycle rate** is adjusted to maintain a hydrogen to fresh feed mol ratio of five to eight. Higher partial pressures of hydrogen tend to increase hyrocracking and to decrease coke lay down on the catalyst. In practice, with higher boiling feed stocks it is often desirable to increase the partial pressure of hydrogen. However, high partial pressures of hydrogen also tend to repress dehydrogenation reactions, other conditions being constant. Low partial pressures of hydrogen usually lead to too rapid deactivation of the catalyst through increased coke deposition.

Catalytic reforming feed stocks.

Straight-run naphthas provide the major feed stocks to platinum reforming processes. The reformability of any feed over platinum catalysts will be governed by the hydro-

carbon composition, the initial and end boiling points of the feed, and the presence of potential catalyst poisons. Distillation ranges of reformer feeds are set by considerations of the final product desired, and by the necessity for obtaining optimum catalyst life and maximum efficiency from the reforming units.

Most reformer feed stocks have an initial boiling point of at least 200 F. Materials boiling lower than this do not contribute greatly to increased octanes after reforming. This light naphtha takes up reformer capacity which can be used more efficiently by the higher boiling components more susceptible to large octane improvements.

Reformate end boiling points are normally about 15 to 25 degrees higher than that of the charge due to the formation of heavy aromatics. As a result, end boiling points of reformer charges are limited to about 400 F or lower, to meet gasoline boiling point specifications.

It is also well to remember that increasing severity on the same end point feed stock will cause an increase in the end point of the reformate. For example, it has been reported that at a 92-octane number, the 90% point of the reformate increased 7 F; at 98-octane number the 90% point increased 17 F; and at 104-octane number the 90% point increased 27 F.[74] These octane numbers are with 3 cc of lead.

As shown in Table 2, the naphthenes and naphthenes plus aromatic contents of feed stocks vary depending on the source of the feed. Correlations are available whereby reforming yields can be predicted from readily measured properties of the charge naphtha.[82] In these correlations use is made of a modified feed characterization factor (K′) which is defined below.

$$K' = \sqrt[3]{\text{Engler 50\%, °R}/\text{SG at 60 F}}$$

where

°R = degrees Rankine

SG = specific gravity of feed

Correlations between this modified characterization factor and clear octane number, C_5^+ yield, iso-and normal butane yields, propane yield, light gas and hydrogen yields have been obtained. In setting up these correlations, the author also took into account the effect of catalyst age and pressure on reforming yields. Fig. 8 shows the correlation between the C_5^+ reformate yields and the C_5^+ reformate F-1 clear octane number for a West and East Texas, Venezuela, and Gulf Coast naphthas.

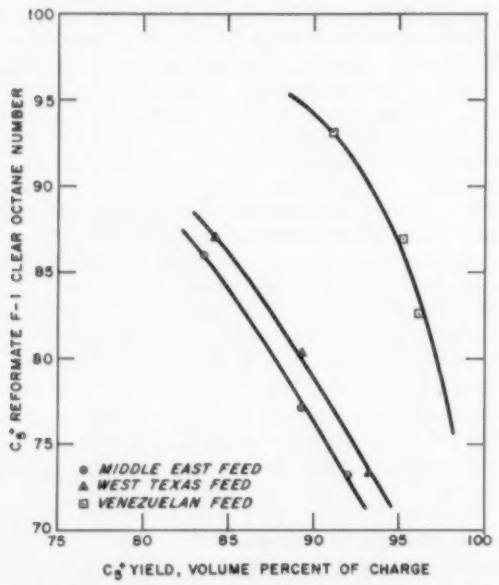


FIG. 8. Clear octane number of C_5^+ reformate vs C_5^+ yield for feeds from various crude sources.

It has been reported that lowering the initial boiling point of a normal reformer feed from 200 to 150 F will result in a decrease in octane number of the reformate by 2.5 clear octane numbers.[71] Normally little increase is seen in octane number as the end boiling point of the naphtha is raised above 400 F. However, where the heavy aromatics are being sought, and rerun facilities are available, some refiners will increase their end boiling point of the reformer feed stock.

Recently, several companies have built separate reforming units for processing light and heavy reformer feed stocks. Table 13 shows a comparison of the operating conditions used in two reformers and the properties of the feeds and products.[84] The high end point feed has a boiling range of 203 to 387 F. The feed for the second unit has a boiling range of 167 to 300 F.

A basic difference in the two units is the lower operating pressure of the light end point feed unit. This unit operates with a pressure of 300 psig on the product separator, with the reactor being somewhat higher. The heavy end point feed unit operates at 400 psig separator pressure. This pressure arrangement takes advantage of the charge properties, since it is possible to reform lower boiling point material at lower pressure without excessive coke lay down becoming a problem. The octane-yield relationship for the lighter material is more favorable at the lower pressure. The heavier charge requires a higher pressure to minimize coke deposition on the catalyst.

In many refineries, where coker and visbreaker naphthas are available, the refiner has sought to blend these into his reformer feed stocks. Operations where these unsaturated

Table 13. Reforming of Light and Heavy Feeds.

		H.E.P.	L.E.P.
Temperature F (1-2-3 react.)		925–900–890	975–975–975
Prod. separator pressure (psig.)		450	300–450
Hydrogen-hydrocarbon (mole ratio)		7.8	6.0
Reactor charge, (bbl/hr)		675	667
Stabilized reformate (bbl/hr)		615	540
Reformate yield (vol. %)		85.7	80
Reactor feed—API gravity		52.9	64.0
	I.B.P.	203	167
	50%	286	188
	90%	325	222
	E.P.	387	300
Reformate	API gravity	52.7	60.3
	I.B.P.	100	146
	50%	262	185
	90%	327	231
Res. Oct. No. (+3 ml TEL)		97.1	92.5

Table 14. Reforming of Catalytic Gasoline Fractions.

Fraction boiling range, F.	235–270	270–300	300–340	340–412	235–412
Product yields, vol. % of charge					
C_5+	86.6	90.8	92.0	90.8	91.9
C_4's and C_3's	11.1	7.5	6.3	6.6	6.2
C_5+ reformate octane numbers					
F-1 clear	99.7	103.5	104.5	101.7	101.0
F-1 + 3 cc. TEL	104.2	106.8	107.4	103.6	104.6
Sensitivity (+ 3 cc. TEL)	9.9	9.5	8.6	9.9	10.2
Octane number gained by reforming (F-1 + 3 cc. TEL)	+13.3	+11.4	+9.5	+17.2	+12.3

feed stocks were used have been reported in the literature.[85,86,87] However at the present time, it is realized that successful operation with unsaturated charge stocks requires pretreating to maintain the activity and the life of the reforming catalyst.

The reforming of heavy catalytically cracked gasoline fractions, rich in naphthenes, is also carried out by a number of companies.[71] By choosing the heavier cuts, a majority of the olefins are removed from the reformer charge, and a higher octane reformate will be obtained.

Recent results obtained in the pilot plant reforming of heavy catalytically cracked gasoline fractions are shown in Table 14. These results show that reforming selected cuts, at moderate severity, produces C_5^+ reformates having leaded research octane numbers up to 107.4 at 90 vol % recovery. These reformates show a blending octane number of about 106 with a sensitivity of about 5.5 when blended at 25 vol % concentration in a 105-leaded research octane base fuel.

It was estimated that processing costs would be less than two cents per gal if spare reformer capacity is available. This figure includes changes in refinery yield structure. These costs will increase to about four cents per gal if virgin naphtha must be backed out in order to make room for the heavy catalytic gasoline.

The addition of heavy catalytic cracked gasoline fractions to a straight-run reformer feed will require pretreatment of the entire feed in order to maintain the activity, selectivity and life of the catalyst. In the pretreating operation, not only will the sulfur compounds and other catalyst poisons be removed, but all the olefins present in the catalytic cracked gasoline will be saturated.

Pretreatment of reformer feeds.

As mentioned above, reformer feed stocks containing high concentrations of sulfur, nitrogen, unsaturated hydrocarbons, organic chlorides, and metallic catalyst poisons must be pretreated before the charge is put into the reforming unit. The amount of hydrogen required to pretreat these charge will vary depending on the total amount of these contaminants.

In general, it has been found,[74] that for straight run stocks, the consumption of hydrogen in the pretreater will vary from 2 to 150 cu ft per bbl, depending on the nitrogen and sulfur concentration of the charge. When olefins are also present in the feed stock, further consumption of hydrogen will occur in the saturation of these hydrocarbons. A low sulfur feed stock with a bromine number of 10 will consume about 80 to 100 cu ft of hydrogen per bbl. As a general rule, about 7 cubic feet per barrel of hydrogen will be required to reduce the bromine number by one unit. ★

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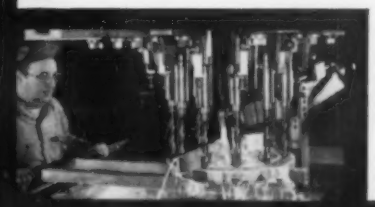

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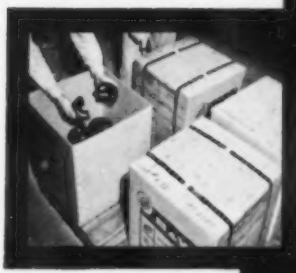

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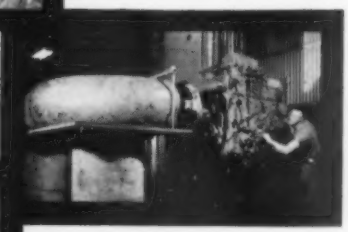

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Potassium Chromium Fluoride
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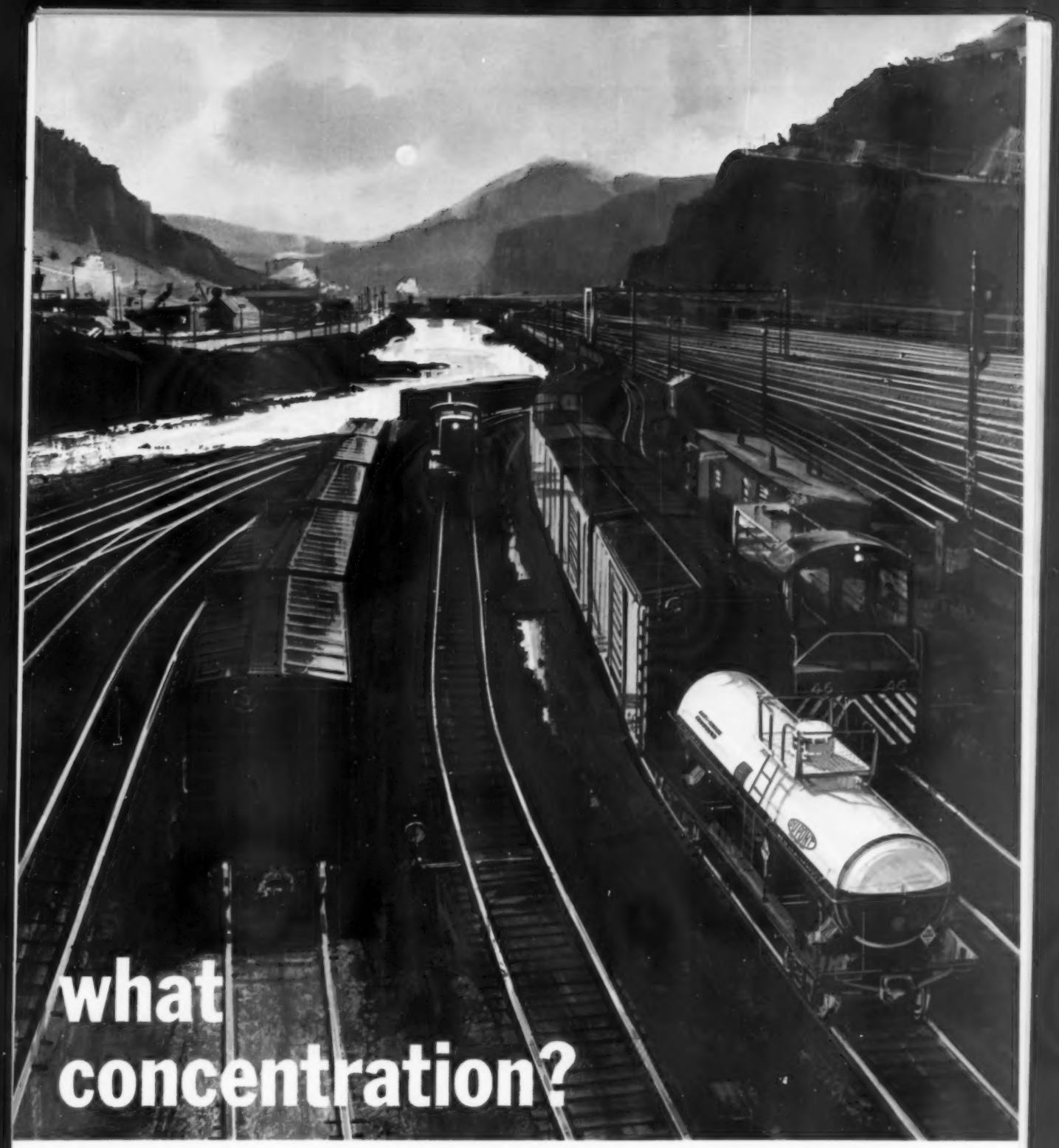

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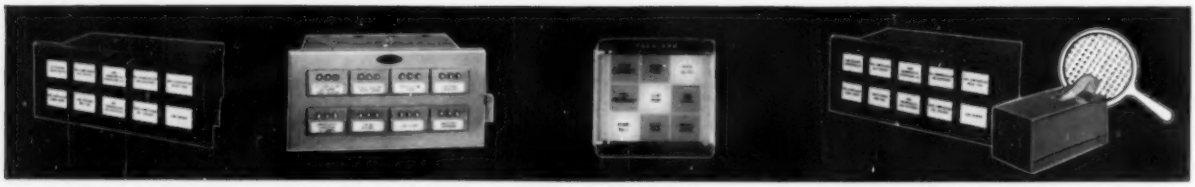

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Part 2, Chapter 2f—Theory of Fractionation—Multicomponent Distillation

DISTILLATION . . . *in view of Modern Developments*

KENNETH F. GORDON, *University of Michigan, Ann Arbor, Michigan*
JAMES A. DAVIES, *Texaco Inc., Houston, Texas*

AS COVERED in the section on Degrees of Freedom, in an ordinary distillation column there are four degrees of freedom which are set by the designer after the feed composition and condition as well as the operating pressure are chosen. Usually two of these are product composition variables which are any two mole fractions or amounts of component specified in the bottoms or distillate. Often this is done as the fractional recovery, or mole fraction of one component in the bottoms and one in the distillate. These specified components are known as the keys. Another degree of freedom is taken up with the setting of the liquid to vapor flow rate ratio at a point, normally by a reflux ratio. Finally, for the column being designed, it is specified that the total number of plates be a minimum.

It was shown that with these specifications there are as many equations as there are unknowns and, from the mathematical point of view, the system is determined although computation of the numerical values may be very tedious. With the advent of widespread use of computers, several techniques for solving a set of equations have been developed and were briefly indicated in a previous part of this series, Computers.

CLASSES OF FRACTIONATION DESIGN METHODS

There are a number of classes of methods for calculating the multicomponent case. They are:

a. plate to plate,
b. solution of a large number of simultaneous equations and algebraic techniques,
c. transient approach to steady state or relaxation,
d. graphical,
e. short-cut, and
f. empirical.

Some of these methods are more accurate than others. Some apply to close separations with only two distributed keys, while others to sloppy separations with a number of distributed keys. A method of each category will be briefly outlined and references to examples will be given as well as references to other methods. There is little need to repeat material which is readily available in the literature. Edmister reviewed these in 1948.[12]

Normally a design engineer or engineering office will choose several methods and have a system whereby they may be readily applied using calculation sheets, design curves and other devices engineers usually develop.

A desirable aim is to have three general methods, one for preliminary cost estimation, one for sloppy separations or non-critical items, and one for close separations.

Quick Method for Preliminary Cost Estimation

A short-cut method that can be done by hand is needed to yield an order of magnitude figure on the capital investment requirement may be obtained.

Here a rough estimate of the number of trays and an approximation of the column diameter are all that is required. These are discussed more fully below. A fast satisfactory route is the Gilliland empirical method[15,16,34] using the values calculated for minimum reflux and minimum trays.

Design for Non-Critical Separation

Here the number of trays is usually small, separation is not exacting, and the distillation column is not the critical item in the process. Thus, the need for high precision in the design is not great. A useful method is that of Hengstebeck and Schubert[22] discussed below.

Design Method for Exact Separation

A rigorous computer program for the final design of critical items would be valuable. Possibly one such as that of Amundson and Pontinen[3] or of Greenstadt, Bard and Morse[18] will be developed to a point of becoming standard.

Until it is available in an organization a plate to plate calculation, while tedious, will always work. These and other computer methods were reviewed in a previous chapter on Computers.

The solution of either of the Quick or Non-critical Methods can be used as the initial solution in some computer methods. This will result in a more rapid convergence and a quicker approach to the final solution.

PRELIMINARY STEPS

Pressure and Temperature

Before the number of plates can be calculated by any method, several variables must be fixed. They include the separation desired and the operating pressure. While all the products of a multicomponent distillation cannot be specified exactly without trial calculation of the desired separation, an estimate of top and bottom composition can be made which will be accurate enough to allow the pressure to be set in the condenser which will be dictated by the cooling water temperature. Except in low pressure or vacuum distillation work, this can be considered to be the pressure throughout the column, for the pressure drop from plate to plate will be negligible relative to the operating pressure. The pressure drop through a tray is usually not over 0.15 psi. The operating pressure and the approximate

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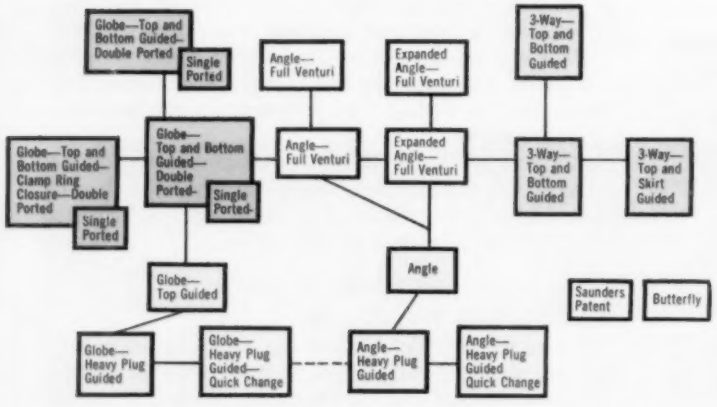

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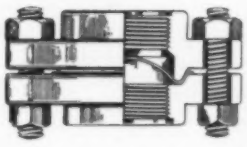

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composition of the bottoms then give the preliminary estimate of the reboiler temperature and that of the heating medium.

Other preliminary considerations are reflux to the top of the column, vapor load to the column from the reboiler, and feed plate calculations including flashing, the effect of superheated vapor feed or supercooled liquid feed. These have been discussed by Edmister.[12]

While not necessary for the design of a distillation column by some methods, it is useful to know the limits or extremes of design for a given separation. These are the minimum trays with total reflux and the minimum reflux with an infinite number of plates. Because of the ease of calculation little effort is required to obtain the minimum number of trays. The minimum reflux is a much more difficult matter and often is only approximated rather than calculated exactly. Both the minimum reflux and the minimum trays are used in the empirical methods of fractionation column design which are covered later.

Minimum plates. In principle the minimum plates may be calculated by any multicomponent method by setting L = V for each pair of vapor and liquid streams passing each other. If the chosen method used assumes constant relative volatility, then it should reduce to the Fenske equation which can be derived directly.

This is

$$\frac{d_l}{d_h} = \alpha^N \left(\frac{b_l}{b_h}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

$\frac{b_l}{b_h}$, $\frac{d_l}{d_h}$ = ratio of amounts of key components in bottoms and distillate respectively

N = number of stages, including 1 stage for reboiler and 1 stage for partial condenser

α = average relative volatility.

By using the average values for the relative volatility at top and bottom a reasonable approximation may be made. This can be improved by taking average values over increments of the column.

Minimum reflux. While a value for the minimum reflux is needed to use empirical methods which are covered below, a precise value is not necessary in some design activities, but an estimate is valuable in order to set a lower limit for the reflux. To handle minimum reflux calculations, it is necessary to have a very clear understanding of the distinction between two classes.

Class I. Here all components are present in appreciable amounts in both the top and bottom products even with an infinite number of plates. This is also known as fractionation with multiple keys or sloppy separation.

Class II. Here some of the components are completely fractionated going entirely to the top or bottom products. This is sometimes known as precise fractionation.

Shiras, Hanson and Gibson[41] have emphasized the difference between the two classes. In the first the point of infinitude or pinch point is at the feed tray while in the second class it is removed and there are two pinch points, one in the rectifying and one in the stripping sections. In special cases there will be additional pinch zones for Class II separations.

For Class I exact analytical solutions for the problem are published. They do not assume either constancy of the liquid and vapor flow rates or constant alpha values.

For Class II exact analytical solutions are not yet available except for constant liquid and vapor rates and alpha value. The usual route is by the later Underwood equations which are discussed in a number of articles. They require the assumption of constant molal overflow and constant relative volatility.

It should be noted that even though Class I separations are frequently termed "sloppy" the minimum reflux requirement is usually larger than that for Class II. Class I separations result in only one pinch zone located at the feed tray while in general Class II separations have two pinch zones, one above the feed and one below the feed. A special case for Class II has an additional pinch zone at the feed. The reflux requirement for this case is determined by the equations for Class I separations.

Class I Separations

Underwood's early method for calculation of a multicomponent system has received some attention and is sometimes used. Various modifications have been introduced to render it more convenient.

For Class I separations Shiras, Hanson and Gibson[41] have presented a good discussion of the early Underwood equations showing that here, where the pinch point occurs at the feed, that neither constancy of reflux or of relative volatility values are assumed in the derivation of Underwood's[46] equations for conditions at the point of infinitude in the rectifying section.

$$\frac{L_\infty}{D} = \left[\frac{(x_A)_d}{(x_A)_\infty} - (\alpha_{A,B})_\infty \frac{(x_B)_d}{(x_B)_\infty}\right] \Big/ [\alpha_{A,B} - 1] \quad . \quad (2)$$

and in the stripping section

$$\frac{\bar{L}_\infty}{B} = \left[(\alpha_{A,B})_\infty \frac{(\bar{x}_B)_b}{(\bar{x}_B)_\infty} - \frac{(\bar{x}_A)_b}{(x_A)_\infty}\right] \Big/ [\alpha_{A,B} - 1] \quad . \quad (3)$$

These can be used at the pinch point at the feed plate. Equation 2 becomes

$$\frac{(L_{\phi+1})_{min}}{F} = \frac{L_f}{F}\left[\frac{D(x_A)_d}{L_f(x_A)_f} - (\alpha_{A,B})_\phi \frac{D(x_B)_d}{L_f(x_B)_f}\right] \Big/ [(\alpha_{A,B})_\phi - 1]$$
$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where $\phi + 1$ refers to the plate above the feed.
For a feed at its boiling point, Eq. 4 becomes the familiar

$$\frac{(L_{\phi+1})_{min}}{D} = \frac{1}{(\alpha_{A,B})_\phi - 1}\left[\frac{(x_A)_d}{(x_A)_F} - (\alpha_{A,B})_\phi \frac{(x_B)_d}{(x_B)_F}\right]$$
$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

while for a feed of saturated vapor at the dew point there may be obtained the equation

$$\frac{(L_{\phi+1})_{min}}{D} = \frac{(\alpha_{A,B})_\phi \frac{(x_A)_d}{(x_A)_F} - \frac{(x_B)_d}{(x_B)_F}}{(\alpha_{A,B})_\phi - 1} - 1 \quad . \quad (6)$$

Equations are also given for feeds which are above the dew point or below the bubble point in temperature. By applying Equation 4 to one component and any other component and then to one of the same components and one other component $L_{\phi+1}$ may be eliminated and $D(x_1)_d$ values for all components may be obtained.

Class II Separations

The previous equations are only valid when all components are present in both top and bottom products. For the many separations falling into Class II, approximate methods or methods with limited exactness are available. The best known is that of Underwood[45] which will be outlined as done by Shiras, Hanson and Gibson.[41] Parameters

Φ are defined in both the rectifying and stripping sections by means of the equations.

$$\sum_i \frac{\alpha_{ir} D(x_i)_d}{\alpha_{ir} - \Phi} = V \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\sum_i \frac{\alpha_{ir} B(x_i)_b}{\alpha_{ir} - \Phi'} = -\overline{V} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The first equation of the pair has as many roots or values of Φ as there are components in the top products and the second has as many roots as there are components in the bottom products. The roots, Φ, of the first equation will be between the value of each pair of α and one will be smaller than the lowest α. For Eq. 8 there will be found one root lying between each pair of alphas of components which are found in both the top and bottom products. At minimum reflux these roots will be identical to those in the solution of Eq. 7 which lie between the appropriate α's. The common roots may be obtained directly by adding Eq. 7 and 8 to give

$$\sum_i \frac{\alpha_i F(x_i)_F}{\alpha_i - \Phi} = V - \overline{V} = V_f \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Any one of these common roots may be substituted to give either V_{min} or L_{min} by

$$V_{min} = L_{min} + D = \sum_i \frac{\alpha_{ir} D(x_i)_d}{\alpha_{ir} - \Phi_j} \quad . \quad . \quad (10)$$

$$L_{min} = \sum_i \frac{\Phi_j D(x_i)_d}{\alpha_{ir} - \Phi_j} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

In the case where the values of α vary with temperature, Shiras, Hanson, and Gibson suggest that they be evaluated at the estimated feed plate temperature with the calculated minimum reflux to be regarded as that reflux at the plate. The external reflux can then be found by enthalpy balance.

A recent method by Bachelor[4] is said to give exact values for minimum reflux in Class II problems. He employs a set of equations which are basically absorption factor equations. As the pinch zone temperatures are unknown they must be assumed. A calculation is made which gives the value of the equilibrium ratio of the heavy key which in turns gives a temperature. If this temperature is not that assumed, the cycle is repeated using the calculated temperature. Calculation tables are given for the case of mixed saturated vapor and liquid feed as well as for supercooled liquid and superheated vapor. Comparisons are made with the Underwood[45,46] and Colburn[11] methods.

When the assumptions of constant mole flow rates and constant reflux ratios are not valid enough to yield a satisfactory answer, then a so-called exact calculation must be made taking into account the change in these factors. A well-used technique is that outlined by Brown and Holcomb.[8] Essentially, it is hunting for the minimum reflux by trial using a Lewis and Matheson[28] technique with material and enthalpy balances around each plate. From an estimate of minimum reflux by another technique, the compositions and flow rates of the streams at the two points of infinitude are estimated. Enough heavy components are added to the stream at the point of infinitude in the rectifying section and light components to the point of infinitude in the stripping section so that when plate by plate calculations of the Lewis and Matheson type are made from the two points of infinitude to the feed plate they match. If necessary, enthalpy balances can be made in each step and the flow rates adjusted. This method has been presented in a modified form by Jenny.[24]

Shiras, Hanson and Gibson[41] also discuss the trial and error calculations for minimum reflux based on the Thiele and Geddes[43] method. They point out that this method is usually too time consuming for any but a research calculation program. However, with the use of computers, it may be that a satisfactory program will be developed using a method now too tedious to use.

In ordinary design work the method based on Underwood's[45] equations for Class II is normally satisfactory, for as one is not operating at minimum reflux, its calculation is not critical.

Actual Reflux and Theoretical Trays

The determination of the required number of 100% efficient or theoretical trays and the actual reflux quantity to affect the desired separation will be discussed below. Most of the design methods calculate directly the actual theoretical trays and reflux requirement. The empirical method on the other hand requires the determination of minimum trays and reflux and the actual theoretical trays and reflux are taken from a correlation.

The actual number of trays required will have to be determined from the efficiency of the trays expected. Tray efficiencies are discussed in a later part of these series and a method for their determination is recommended. Except for binary mixtures the efficiency of a tray will be somewhat different for each component handled. It is suggested that the efficiencies of the key components be averaged and taken as the tray efficiency.

DESIGN METHODS

Plate to Plate

The most popular technique for calculating the number of theoretical plates is a modified Lewis-Matheson[28] method for plate to plate calculations. Essentially, it consists of setting a reflux ratio and hence a liquid rate and a vapor rate. It is necessary to assume or guess the composition of both distillate and bottoms. By material balances and equilibrium relationships, with or without enthalpy balances, the composition on each theoretical plate is calculated working from each end to the feed plate. The temperature on each plate must be approximated by a bubble point or dew point method in order to choose the correct equilibrium relationship. The feed plate composition is calculated twice, once from each end. Seldom will these two values match on the first set of calculations. The assumed end compositions must then be altered and the calculation repeated to make a mesh or a match on the feed plate. It may be necessary to repeat this several times to achieve a satisfactory agreement. Often it is not necessary to calculate all the way back to the ends of the column it being sufficient to drop back only a few stages on either side of the feed plate at which points the components become negligible. In many cases the calculation can be greatly simplified by assuming constant molal overflow so that enthalpy balances are not necessary. Examples of such calculations are given in texts[34] and the literature.[12,28]

Even with the assumption of constant mole liquid and vapor rates and constant relative volatility of each component the traditional method involves a double trial and error calculation. The end conditions are assumed and each plate is calculated by trial. Only if the end conditions are correctly assumed will there be a meshing of the calculated composition with the assumed one at the opposite end or the one calculated on the mesh plate. For Class II separations this method falls down since the components missing in the product streams must be arbitrarily added in some

tray. While this can be done, it results in a questionable solution.

Some computer programs are available for plate to plate calculations as mentioned in an earlier part, Computers.

Solution of a Large Number of Simultaneous Equations and Algebraic Techniques

Rather than attempting to calculate each plate going through the column plate by plate, the end conditions might be calculated directly by algebraically eliminating the intermediate values or, in another approach, the end and all other conditions could be obtained simultaneously by solving all the equations for all variables.

1. Calculation of End Values Only.

Method of Eshaya. A recent method proposed by Eshaya[18] appears to be the simplest of its type and to offer a great advantage in ease of calculation. With it there is no need to calculate compositions on intermediate plates, thus eliminating any trials on the intermediate plates and the trials are minimal, being only for end conditions.

By using the equilibrium relationship

$$y = Kx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and the operating line equation, counting plates upward

$$y_n = p^* x_{n+1} - a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

there results for each component a rectifying section equation and a stripping section equation of the form

$$x_n = x_0 E_1 + \frac{a}{p^*} E_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

where x_o is the liquid composition on the zeroth stage and x_n is the liquid composition on the nth stage of the section. E_1 and E_2 are given functions of the number of stages n, Q and a numerical parameter b.

The defining equation

$$Q = \frac{K_{ao}\alpha}{p^*} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

gives a different Q for each component because α varies for each component while K_{ao}, the equilibrium ratio for the reference component used for relative volatility α, and the operating slope p^* are fixed in the section of the column. The numerical factor, b, is the same for every component throughout the whole section, but being unknown, it must be assumed. Then x_n is calculated for each component by Eq. 14. If $\Sigma x_n = 1$, then the correct value of b was assumed; if not, a new one is chosen and the calculation repeated.

The determination of the minimum number of plates is straightforward for $p^* = 1$ at total reflux and the equations reduce to the Fenske type. For assumed end conditions, the number of stages required for the assumed separation of each component is directly calculated without trial. End conditions are then altered so that the number of stages required for each component is the same. While this method could yield minimum reflux by assuming various values for the p^*'s, it is not recommended.

Two examples are given where Eshaya compares his method with the stage by stage technique.

Method of Acrivos and Amundson. In a series of papers Acrivos and Amundson[1] have developed the analytic solution of the equations for steady-state operation with the assumptions of constant relative volatility and constant vapor and liquid mole flow rates. They give methods for calculating the number of plates, and minimum reflux for multicomponent, complex or continuous and semi-continuous mixtures. They also extend the method to packed columns. The perturbation method is used to obtain an approximate solution for the case of variations in relative volatilities, flow rates and plate efficiencies.

The series involve mathematics usually beyond the background of most chemical engineers such as the Riemann Zeta functions, Kronecker symbol and Dirac delta functions. As such it will not be used by the average design engineer, but would be of interest to those who are concerned with the development of computational techniques.

2. Calculation of all Values Simultaneously

The computer methods of Amundson and Pontinen[3] and Greenstadt, Bard and Morse,[18] covered in the sub-chapter on Computers, are essentially methods of simultaneously solving the set of equations for all the unknowns. In this way, values for all variables are obtained simultaneously.

3. Further Algebraic Methods

The ideal method would be an easily solved algebraic expression for the number of trays and reflux. There have been a number of algebraic expressions presented but none gives an easy solution. Edmister[12] presents a method using absorption and stripping factor equations similar to those used for absorption and stripping processes. He uses average factors. Hachmuth[32] et al. did something similar. Harbert[20] gives equations derived semi-empirically. Underwood[45] and Murdoch[31] give rigorous equations which can be solved for precise fractionation; that is, good separation between two adjacent keys only. They assume constant molal overflow and volatility. Alder and Hanson[2] have given examples for "sloppy" separation using the Underwood equations with the assumption of constant relative volatility constant molal flow rates.

An early expression is that of Smoker[42] which has been used to a limited extent. Tiller[44] and others have attempted to use the calculus of finite differences to the solution of fractionation equations with only partial success.

Transient

In the transient method, which has already been sketched in the chapters on Computers, a composition distribution throughout the distillation column is first assumed. Then by a relaxation or an iteration technique the correct steady state composition distribution is calculated.

This procedure has been developed by Rose, Sweeny and Schrodt.[37] In their article an example is given using a calculational procedure which should be identical to that used to find the time required for a distillation column to achieve steady state.

As the liquid holdup on a plate is known as well as the liquid and vapor flowrates which are set by the reflux ratio a material balance around a plate may be made. By choosing a short enough time period, all streams flowing can be taken to have constant composition with the difference between input and output going to an accumulation term resulting in a change of composition of the holdup on the plate. The material balance on a plate is entirely independent of all other material balances so that a new estimate of the composition of each plate may be made. The procedure is then repeated using the new composition distribution. The calculation is repeated over and over again until all the compositions are constant and no longer changing with iteration number or time.

A convenient initial assumption is that all liquid compositions are that of the feed. In the beginning of the calculation the approach to steady state is rapid but afterwards is slow. The calculation may be accelerated as done by Rose, Sweeny and Schrodt[37] where they extrapolate the concentration vs. time or iteration number, including it as part of the program for the medium speed digital computer employed by them.

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Their article shows that for a ternary system the composition of a component on a tray may decrease then increase before leveling out with iteration number.

The approach can be readily adapted to the problem of start-up time and time to achieve steady state.

Graphical

A two component separation can be handled graphically in two dimensions by the McCabe-Thiele or Ponchon-Savarit methods while a three component fractionation can be calculated graphically in three dimensions as shown in a series of articles by White.[47] Just as a three dimensional mountain can be plotted in two dimensions by employing a contour map so ternary problems could be projected to two dimensions as in the Chapter on Ternary Distillation. It is clear that a graphical method for n-components would require n-dimensional space or possibly (n-1) dimensions utilizing contours or projections.

To use the two dimensions of an ordinary graphical procedure it is seen that the problem must be reduced to that of a ternary and preferably, a binary. This has been done by Hengstebeck[21,22] yielding a useful technique.

A satisfactory design method in fractionation with multiple keys for non-critical columns is that of Hengstebeck as modified by Hengstebeck and Schubert[22] and Hengstebeck.[21] Here the system is considered as a two component pseudo-binary consisting of adjacent keys. A McCabe-Thiele diagram is drawn for the binary consisting solely of these keys. The conditions at the feed tray are approximated by trial. The slope of the operating lines for each of a few trays above and below the feed are calculated by a tray to tray calculation. These are found to approach the limiting slope given by the equations of Jenny.[24] The compositions at each end are calculated tray by tray, while intermediate trays are stepped off between the limiting operating line and the equilibrium line on the pseudo-binary McCabe-Thiele. Development of the equations and a complete example are available. A method for calculating the distribution of the non-key components is given.

Other methods are Scheibel[38] and Bailey and Coates.[6,7]

Short Cut Methods

Many times a short cut method for an approximate answer is desired. Often this occurs in cost estimation work. Because of its simplicity, it is desirable to have a calculation requiring only the end conditions to obtain the number of necessary stages.

One short cut method is that of Gilliland[14] who employs the relative volatility α and the relative operability β of the two key components. The relative operability is obtained by rewriting the operating line equation as

$$\frac{V}{L}\frac{y_{n+1}}{x_n} = 1 + \frac{D}{L}\frac{x_d}{x_n} \quad . \quad . \quad . \quad . \quad . \quad (16)$$

counting trays from the top of the column.

If the above equation is written for both the light and heavy keys and dividing that for the light key by that for the heavy there results

$$\beta = \frac{1 + \left(\frac{D}{L}\right)\left(\frac{x_d}{x_n}\right)_{\text{light key}}}{1 + \left(\frac{D}{L}\right)\left(\frac{x_d}{x_n}\right)_{\text{heavy key}}} \quad . \quad . \quad . \quad (17)$$

for the rectifying section.

Similarly for the stripping section there results

$$\beta = \frac{1 - \left(\frac{B}{L}\right)\left(\frac{x_b}{x_m}\right)_{\text{light key}}}{1 - \left(\frac{B}{L}\right)\left(\frac{x_b}{x_m}\right)_{\text{heavy key}}} \quad . \quad . \quad . \quad (17a)$$

This yields for any section of N stages

$$\frac{x_{N,\ \text{light}}}{x_{N,\ \text{heavy}}} = \left(\frac{\alpha}{\beta}\right)^N \frac{x_{0,\ \text{light}}}{x_{0,\ \text{heavy}}} \quad . \quad . \quad . \quad (18)$$

This equation should be applied between the feed and the bottoms and also the feed and distillate. It frequently is applied, however, between the distillate and bottoms.

Another method for quick calculation is the absorption factor method of Brown.[10,26] Here the distillation column is treated as an absorber on top of a stripper. By making a stage to stage calculation, the following formulas result for the absorbing or rectifying section:

$$\frac{Y_{n+1} - Y_1}{Y_{n+1} - Y_o} = \frac{A^{n+1} - A}{A^{n+1} - 1} \quad . \quad . \quad . \quad . \quad . \quad (19)$$

and for the stripping section

$$\frac{X_o - X_m}{X_o - X_{m+1}} = \frac{S^{m+1} - S}{S^{m+1} - 1} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

where

$$A = \frac{L}{KV} \text{ and } S = \frac{KV}{L} \quad . \quad . \quad . \quad . \quad (21)$$

$Y_{n+1} - Y_1$ = moles of component absorbed per mole of entering gas.

$Y_{n+1} - Y_o$ = moles of component absorbed per mole of entering gas if the gas leaving the absorber were in equilibrium with the liquid entering, X_o.

similarly for $X_o - X_n$ and $X_o - X_{n+1}$ the subscripts m and n referring to the stripping and rectifying sections. The correlations of Hachmuth and co-workers[32,33] are somewhat more involved, but result in a determination of the feed tray. The other two methods do not give the feed tray location.

The methods do not give identical results. Each requires the calculation of the minimum reflux ratio. Once these results are available, it is a simple matter to calculate the required number of trays.

There have been a variety of methods published covering the calculation of the minimum reflux. These include Gilliland,[15,16,34] Underwood,[45,46] Colburn,[11] Brown and Holcomb,[8] Scheibel and Montross,[39] Bailey and Coates,[5] and Mayfield and May.[30] Some of these are empirical equations,[11] others make assumptions as to location and compositions of the pinch zones and feed tray compositions which are incorrect. For the usual case, there is no pinch zone at the feed, the ratio of key compositions in the pinch zones and on the feed are not directly related to or equal to the feed compositions or to one another. These assumptions have been made in some of these methods. Most assume close fraction of two keys with no other distributed components and cannot be applied conveniently to less precise separation. Underwood's method[45] appears to be the best.

Since Gilliland's early minmum reflux equation[35] is frequently used for preliminary design work, it will be given here:

$$\left(\frac{L}{D}\right)_{\text{min}} + 1 = \left\{\left[\alpha_h + \alpha_l\left(\frac{x_l}{x_h}\right)_l\right]\frac{x_{hb}}{\alpha_l - \alpha_h} + \sum_{h^+}\left(\frac{\alpha_h x_{hb}}{\alpha_l - \alpha_h}\right)\right.$$

$$\left. + \left(\frac{D}{B}\right)\left(\frac{\overline{V}}{V}\right)\sum_{l^-}\left(\frac{\alpha_l x_{ld}}{\alpha_l - \alpha_h}\right)\right\}\left[\frac{x_{ld}}{\left(\frac{x_l}{x_h}\right)_l} - x_{hd}\right]\frac{1}{x_{hb}} \quad . \quad . \quad (22)$$

where $\sum_{h^+}$ indicates the summation of terms for components heavier than the heavy key and $\sum_{l^-}$ the summation of all terms lighter than the light key while $(\ )_i$ signifies at the intersection of the two operating lines.

$$\left(\frac{x_l}{x_h}\right)_i = \frac{x_{lF} + \frac{B}{V}(p+1)\,x_{lb}}{x_{hF} + \frac{B}{V}(p+1)\,x_{hb}} \quad . \quad . \quad (23)$$

where

$$p + 1 = \frac{V - \bar{V}}{F} \quad . \quad . \quad . \quad . \quad . \quad (24)$$

This equation is simpler to use than his more recent equation, but is somewhat less accurate.

Empirical Methods

Empirical methods are the most popular in use and they give quick and fairly accurate solutions. These methods involve the computation of the minimum reflux and tray requirements and then the determination of the actual reflux and number of theoretical trays by resorting to an empirical correlation.

As the number of plates required for a given separation in a distillation column and the operating ratios L/D or L/V have the same boundary conditions, total reflux and minimum reflux it might be expected that there would tend to be a correlation between the ratio $(n+m)/(n+m)_{min}$ and some function involving L/D and $(L/D)_{min}$ or L/V and $(L/V)_{min}$.

Four empirical correlations were developed independently by Gilliland,[16] by Brown and Martin,[9] by Hachmuth[32,33] and co-workers, and Mason.[29] In each case stage by stage calculations were made for a large number of systems, mostly binary, but with some multicomponent systems. The results are plotted yielding the empirical correlation.

Gilliland used

$$\frac{N - N_{min}}{N+1} \text{ vs } \frac{\frac{L}{D} - \left(\frac{L}{D}\right)_{min}}{\frac{L}{D}+1}$$

while Brown and Martin use

$$\frac{N}{N_{min}} \text{ vs } \frac{J}{J_{min}}$$

where $N = n + m$ is the total number of stages

$$J = \left(\frac{L}{V}\right)_S \left(\frac{V}{L}\right)_R - 1 \quad . \quad . \quad . \quad . \quad (25)$$

ABSORPTION AND STRIPPING

Absorption and stripping columns can always be calculated on a stage by stage basis with initial assumptions of end conditions, calculation by trial on each plate (for the temperature may be unknown) and then a check at the end of the column to see how closely the assumed end conditions match those calculated. A recalculation is required if the matching is poor. In the usual case, equilibrium is assumed on each stage so that ideal stages are calculated. Later in this series, rate and non-equilibrium considerations will be examined.

To circumvent the plate by plate calculations several methods have been proposed and are reviewed by Edmister.[12] These are the graphical methods known as the Sherwood Method, (Lewis Method) and various Absorption Factor Methods, namely the Kremser-Brown,[10,26] and the Horton-Franklin.[23] Hachmuth[32] discusses the Absorption Factor Method.

As these are adequately covered in the references and examples compared against plate by plate results, they will not be repeated here except for one.

The Horton-Franklin Method, which has been found convenient, will be sketched. First, the derivation will be indicated. A material balance around a plate m of an absorber where plates are numbered downward as

$$L_o(X_m - X_{m-1}) = V_{m+1}(Y_{m+1} - Y_m) \quad . \quad . \quad (26)$$

Assuming equilibrium between vapor and liquid to be given by

$$y_m = Kx_m \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and defining the absorption factor A by

$$A_m = \frac{L_m}{K_m V_m} \quad . \quad . \quad . \quad . \quad . \quad (27)$$

There results the general equation for absorption

$$Y_n = \frac{(A_1A_2A_3\ldots A_{n-1} + A_2A_3\ldots A_{n-1} + \ldots + A_{n-1} + 1)Y_{n+1} + A_1A_2\ldots A_{n-1}\frac{L_o}{V_b}X_o}{A_1A_2A_3\ldots A_n + A_2A_3\ldots A_n + \ldots + A_n + 1} \quad . \quad . \quad . \quad (28)$$

If an average or effective absorption factor A can be used or if all A's are equal then this becomes

$$\frac{Y_{n+1} - Y_1}{Y_{n+1} - Y_o} = \frac{A^{n+1} - A}{A^{n+1} - 1} \quad . \quad . \quad . \quad . \quad (29)$$

For stripping a similar equation can be derived

$$\frac{X_{n+1} - X_1}{X_{n+1} - X_E} = \frac{S^{n+1} - S}{S^{n+1} - 1} \quad . \quad . \quad . \quad . \quad (30)$$

where X_E is the composition of the liquid which would be in equilibrium with the entering vapor.

The equations are exact and as yet have no assumptions. The estimation of conditions on the plates so that $A_1, A_2 \ldots A_n$ can be calculated constitutes the heart of the method. Horton and Franklin have assumed that a constant percent absorption takes place on each plate and the temperature change is proportional to the absorption. This results in

$$\left(\frac{V_1}{V_{N+1}}\right)^{1/N} = \frac{V_m}{V_{m+1}} \text{ and } \frac{V_{N+1} - V_{m+1}}{V_{N+1} - V_1} = \frac{T_N - T_m}{T_N - T_o}$$

$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31, 32)$$

The resulting assumed temperature and flow distribution may differ widely from that actually achieved, yet the number of plates required will agree closely with that given by plate-to-plate calculation.

With the assumed temperature and at flow rates, A for each stage can be calculated and the absorption calculated for each component. The total absorption is then compared with that assumed.

Similar considerations hold for stripping. A short cut method is given by Horton and Franklin. It has an effec-

tive absorption or stripping factor in Eq. 29 and 30. This is obtained by examination of the expression involving the A's which will show that for the light component the effective absorption factor will correspond to a position near the bottom of the absorber and for the very heavy components in the middle of the absorber. This is given by the Table I.

As this assumes a constant value of A and S which normally implies constant values of K there is a difficulty of choosing a suitable average, for K in distillation is often a strong function of temperature although α is not. Once a value for K has been chosen the calculation is easy for plots of the function are available.

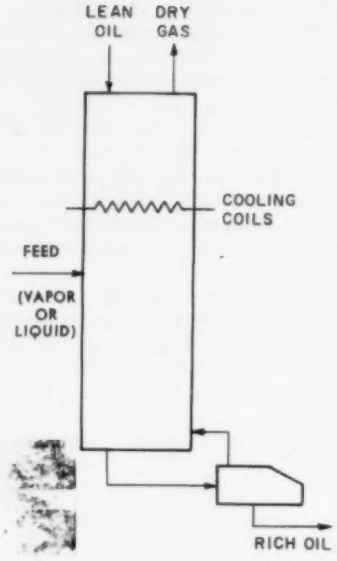

FIG. 1. Rectifying Absorber

Rectifying Absorbers. A rectifying or fractionating absorber combines the aspects of an absorber and a fractionating column. A schematic flowsheet is shown in Fig. 1. In the upper or rectifying section a lean oil is fed to remove the heavy components from the "dry" top gas. In the lower or stripping section the vapor generated in the reboiler serves to strip light components from the bottom liquid. The feed, consisting of a rich oil[17,36] or a rich gas[25] enters in the middle of the column between the stripping and rectifying sections.

Because the mole flow rate of each phase changes from plate to plate due to stripping or absorption as heavy components are absorbed and light components stripped the simplifying assumption of constant molal overflow cannot be used except for an approximation or first trial. A trial and error plate to plate calculation with material and enthalpy balances must be made over part or all the column.

An absorption factor design method has been described[25] but it is known to give inaccurate results. While a tray to tray calculation is regarded as the best, it is tedious and time consuming. Efforts have been made by engineers to develop a short cut method. One that has been used successfully is to calculate the rectifying section as an absorber and do a tray to tray calculation on the stripping section. Such has been described by Hannah.[19] Another has been to calculate the column as a multi-component fractionator on a lean oil free basis using the result as the first trial for the tray to tray calculation.

TABLE 1. Location of Effective Absorption Factors.

A (or S)	*m/N**
0-0.1	1.0
0.1-0.4	0.9
0.4-1.0	0.8
1.0-4.0	0.7
Above 4.0	0.6

*m = plate corresponding to effective factor; N = total number of theoretical plates.

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Nomenclature

A = absorption factor
a = parameter, Eq. 13
B = bottoms product molal flow rate
b = amount in bottoms
D = distillate product molal flow rate
d = amount in distillate
E = parameter, Eq. 14
F = feed molal flow rate
J = parameter defined by Eq. 25
K = equilibrium ratio
L = liquid phase molal flow rate
m = stage number, usually stripping section
N = total number of stages
n = stage number, usually rectifying section
p = parameter defined in Eq. 24
p* = parameter defined in Eq. 13
Q = parameter defined by Eq. 15
S = Stripping factor
T = temperature
V = vapor phase molal flow rate
X = moles per mole of entering liquid
x = liquid phase mole fraction
Y = moles per mole of entering gas
y = vapor phase mole fraction
α = relative volatility
β = relative operability
Σ = summation
ϕ = parameters defined in Eq. 7 and 8

Superscript

' = stripping section
— = stripping section

Subscript

A = component
ao = component a on zeroth plate
AB = A with respect to B
b = bottom
B = component
d = distillate
E = equilibrium
f = feed
F = feed plate
h = heavy key
hd = heavy key in distillate
hF = heavy key on feed plate
h+ = all components heavier than the heavy key
i = general component
ir = general component i with respect to r
j = general values of parameter ϕ
l = light key
ld = light key in distillate
lf = light key on feed plate
l- = all components lighter than the light key
m = plate number in stripping section
min = minimum
n = plate number in rectifying section
N = plate number
o = entering
S = stripping section
R = rectifying section
r = reference component on which relative volatilities are based
∞ = at point of infinitude
1, 2 = identifying number
ϕ = feed plate

Here's your Product & literature Index for May

Acrylonitrile . . . is subject of new 25-page booklet that gives information on physical properties; reactions; applications, specification limits; test methods; storage, handling, and shipping; toxicological properties, and selected literature references. *Union Carbide Chemicals Co.*
Circle number (41) on reply card.

Air-powered operators . . . provide automatic or pushbutton remote control of ball valves. Vertically mounted operators available for valves from ¼ through 8-in. sizes; horizontally mounted cylinder-and-lever type operators for valves from 3 through 8-in. sizes. Both are sold integrally with the valves or separately for installation on valves already in service. *Hills-McCanna Co.*
Circle number (42) on reply card.

Automatic Meterman . . . provides a completely dependable and automatic method for utilizing as many as 40 circular charts in a single recorder. It disengages charts, one by one, at pre-selected times, dropping them by gravity into a self-contained storage box. Any number of recorders can be changed at the identical moment, making it possible to automatically correlate charts with master meter charts without multiple computations. Bulletin available. *Maeder-Squier Co.*
Circle number (43) on reply card.

CM-3 analog computer-controller . . . provides real time control for fractionating towers, butadiene processing, and other multi-variable processes. Either feed-ahead or feedback computation techniques may be employed. Modular construction allows custom units for each application. Unit is also suitable for operator guidance or equation solution for engineering design and analysis. Approximately an order of magnitude improvement over the previous model has been achieved. *Dresser Electronics.*
Circle number (44) on reply card.

Circular prestressed concrete tanks . . . are treated in 16-page brochure containing engineering and construction data on the basic tank elements such as floor, base, walls, and the dome or roof. Includes section on the economic advantage of prestressed concrete tanks and a new tank capacity chart. *Preload Co.*
Circle number (45) on reply card.

Ball valves . . . available in carbon steel to ASA 300 lb (some sizes 600 lb) and in semi-steel, ASA 200 and 400 lb WOG . . . are detailed in Catalog 1000. *W-K-M, Division of ACF Industries.*
Circle number (46) on reply card.

Circular psychrometric calculator . . . converts wet and dry-bulb temperatures to dew point or relative humidity values. Calculator, 11 in. in diameter, is engraved on both sides with precise scales and instructions. Catalog 661 gives details on this and rest of line of scientific instrumentation for precision measurement and control of relative humidity. *Hygrodynamics, Inc.*
Circle number (47) on reply card.

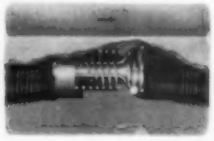
Detailed application data . . . on Cabinetrol grouped power control panels, which utilize standard components arranged to customer's specific requirements . . . is contained in 16-page Bulletin GET-3041. *General Electric Co.*
Circle number (48) on reply card.

Ductile iron globe and angle valves . . . TA Series . . . are discussed in new catalog that gives complete details on pressure-temperature ratings, materials, dimensions, and flow characteristics. *Bastian-Blessing Co.*
Circle number (49) on reply card.

CIRCLE SEAL

CHECK VALVE

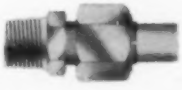
Series 2349R



10,000 PSI in-line check valve constructed of Type 416 stainless steel. All sizes from ⅛" to ¾" pipe. Can be furnished in brass or aluminum at 5,000 PSI rating. Many sizes in Texas stock.

FLODAR SELF-FLARE TUBE FITTINGS

Makes its own flare when tightened. Sizes to fit ⅛" to 2" O.D. tubing. Standard material is carbon steel. Available in stainless steel and aluminum. Many sizes in Texas stock.



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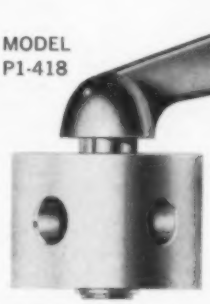
MODEL P1-418



CIRCLE SEAL 4-WAY SELECTOR VALVE

CHROMATOGRAPHIC SYSTEMS ...PRECISION CONTROL

Positive sealing from —14.7 to 100 psi. Temperatures —40° to 350°F. Limited flow passages—minimum dead volume. Body anodized aluminum or 303 SS. Easy 90° rotation. ⅛" connections.

The perfect answer for chromatographic or precision test systems. Either P1-418 or P2-418 (double P1-418 without crossport connections) are ideally suited for selecting, back-flushing or alternating columns. Crossport leakage is entirely eliminated by specially machined O-Ring grooves. O-Rings top and bottom of valve completely eliminate body leakage. Rings are replaceable without removing valve from the line. No adjustment required . . . no valve seats to replace. Special 90° rotation handle visually indicates position.

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CIRCLE SEAL
precision valves

. . . one of a series presented by Western Supply Company, Tulsa, to improve the "I. Q."* of engineers . . . (*"Income Quotient")

IMPACT A RESULT OF CONTACT: PUBLIC SPEAKING NOT AN END, BUT A VITAL MEANS TO AN END

There certainly is no better tool in developing executive or management qualifications than through public speaking. Spoken words are a powerful tool of business. They are used to organize, motivate, coordinate, control, and train.

Since an executive must achieve results through people, he must be able to plan and organize. As a leader, he must be able to motivate and inspire people to action; he must make himself understood. He must have purpose and the will to make other people aid that purpose.

A speaker, too, achieves his results through people. He, too, must be able to plan and organize; must lead; must be able to motivate and inspire others to action; must make himself understood. The speaker must have a purpose and the will to make others aid that purpose. The skills of the executive are identical with those of a speaker, in these areas.

It is not surprising, then, that aspiring leaders in business and industry are judged by their associates and superiors by their abilities to communicate, to a great extent. It is not surprising that an executive can sell himself, can attain greater authority by broadening his capacities for directing and leading, through oral communication.

Words have great power, particularly the spoken word. Words give you contact with other men, and if you use them effectively, they give you—*impact*. That impact is multiplied as you develop your ability to speak, and as you speak to more important audiences.

If you are a novice in public speaking you are not alone. No more than 25 per cent of our speakers could qualify as "veterans."

Like conversation, speaking before an audience is based on sincerity and belief. It involves conviction and concern. The public speaker is most convincing when he is least artful, when he is most natural, and above all, when he is sincere.

Effective speaking is not an accident. It is not the special endowment of a few. While talking before many listeners may come naturally for a few, it is, by and large, a learned art. It consists of an idea, phrased simply, and delivered with conviction and with an expressive voice.

FOOTNOTE: the foregoing paragraphs are a direct quotation from another of Western's "personal-professional development" series. Booklet E-8, titled "Public Speaking: Impact A Result of Contact" a copy of which is yours upon request, without obligation. Write to WESTERN SUPPLY COMPANY, HEAT EXCHANGER DIVISION, P. O. Box 1888, Tulsa, Okla. — **where supervision contributes greatly to the manufacture of heat exchangers of the highest quality, and where personal attention to detail is our watchword.**

Condulets for hazardous locations . . . are discussed in 60-page bulletin that quotes National Electrical Code Articles 500-503 and 510-517, giving company recommendations for condulets meeting the various code requirements. Has more than 300 product photos, installation photographs, and drawings. *Crouse-Hinds Co.*

Circle number (50) on reply card.

Electroscanner . . . automates chart processing by scanning an orifice meter chart, computing and printing data, and punching a card every 15 minutes. In one 8-hr day approximately 2000 flow charts can be processed by an unskilled operator. *UGC Instruments.*

Circle number (51) on reply card.

Featherweight flexible joint . . . providing gimbal and swivel movement for cryogenic piping . . . has desirable features for handling liquid oxygen, virtually all other fluid chemical or petrochemical oxidizers and rocket fuels, as well as liquefied gases and chemicals in industry, within the temperature range from —325 to +275 F. Available in 2, 3, 4, 6, 8, 10, and 12-in. sizes, with welding or flanged ends, for operating pressures to 200 psi. *Barco Manufacturing Co.*

Circle number (52) on reply card.

Fired immersion heaters . . . for heating asphalt, Bunker "C" oil, and other liquids in tanks for loading, pumping, blending, or storage . . . are detailed in new catalog. Specially designed perforated fin maintains high rates of heat transfer while accelerating thermal currents within the tank. *Brown Fintube Co.*

Circle number (53) on reply card.

Gage-O-Matic . . . new liquid level indicating control . . . provides trouble-free and accurate visual read-out of liquid level variations in refrigerant vessels. Manufactured to order, with single or multiple control switches to provide automatic operation of pumps, valves, indicator lights, alarm bells, compressor shut-down, and signal circuits to ADT or other protective organizations. *H. H. McKinnies Co.*

Circle number (54) on reply card.

Globe and angle type meter and gage line valves . . . forged from stainless or carbon steel . . . are detailed in Folder GP-9, which gives specifications and engineering data. *Henry Vogt Machine Co.*

Circle number (55) on reply card.

Hardfacings for catalyst piping and equipment . . . are described in new bulletin. *Texas Alloy Products Co.*

Circle number (56) on reply card.

Hinged closure bulletin . . . tells of new design changes in company's products for blanking off pipeline ends and tank or vessel openings. *Tube Turns Division, Chemetron Corp.*

Circle number (57) on reply card.

How to select solenoid valves for over 500 corrosive media . . . is explained in 16-page booklet. *Valcor Engineering Corp.*

Circle number (58) on reply card.

Hydrofluoric acid . . . anhydrous and aqueous . . . properties and essential information are detailed in MCA chemical safety data sheet SD-25. *Harshaw Chemical Co.*

Circle number (59) on reply card.

ISA Recommended Practice 26.4 . . . on dynamic response testing of final control elements and actuators . . . is available in draft form to those interested in reviewing and commenting on it before its publication as a tentative recommended practice. *Instrument Society of America.*

Circle number (60) on reply card.

Instruction sheets . . . on the OPW 95-U pressure vacuum vent and 209-U emergency vent . . . go through a step-by-step procedure both for installation and for maintenance of the vents, which are used on bulk storage tanks of petroleum products. *OPW Corp.*

Circle number (61) on reply card.

Karbate impervious graphite Type F centrifugal pumps . . . featuring new carbon-to-carbon rotary seal . . . are explained in Catalog Section S-7253. Four basic pump sizes provide capacities up to 140 gal per min and heads up to 67 ft. *National Carbon Company.*

Circle number (62) on reply card.

Knowledge, study, creative urge, and professional dedication . . . are essential to produce engineering achievement and accomplishment, according to latest booklet in series of "professional advancement" messages. It enumerates 14 "ground rules" for the engineer's consideration. *Western Supply Co.*

Circle number (63) on reply card.

Lectrosonic carbon steel heat exchanger tubing . . . is subject of Bulletin TB-431. *Babcock & Wilcox Co.*

Circle number (64) on reply card.

Low iron insulating castable . . . for refractory lining or maintenance material in controlled atmosphere heating furnaces where exceptionally low iron content is necessary . . . has iron oxide content of only 0.4%. Recommended maximum use temperature is 2200 F with a weight factor of only 55 lb per cu ft. *J. H. France Refractories Co.*

Circle number (65) on reply card.

Miniature air switch . . . the magnet-actuated Pneumation switch for use in totally pneumatic circuits . . . is detailed in Bulletin S-1. *Associated Control Equipment, Inc.*

Circle number (66) on reply card.

New all-use fire extinguisher . . . available in 10 and 20-lb sizes . . . is approved for A, B, or C fires, thus eliminating the fire emergency confusion and delay in finding the right type of extinguisher for the fire. Non-toxic, non corrosive, non-freezing. *American LaFrance.*

Circle number (67) on reply card.

Nuclear gaging systems . . . for measurement of liquid, solid, or slurry levels or interfaces . . . are treated in folder that describes method of operation and gives specifications. *Ohmart Corp.*

Circle number (68) on reply card.

Oil and heat sentinals . . . cut off engines when oil pressure drops to a pre-designated low, or the heat generated rises

above a set danger point. Models available for both liquid fuel and gas and butane engines. *Happy Co.*

Circle number (69) on reply card.

Petro ball valve . . . to control flow of liquid or gas . . . has built-in union ends that simplify installation, operation, and maintenance. Dual seats seal regardless of direction of flow. Seats, available in buna-N, neoprene, and teflon, are interchangeable to meet most media requirements. Valve comes in stainless steel, carbon steel, and brass and in eight sizes, ¼ through 2 in. *Clayton Mark & Co.*

Circle number (70) on reply card.

Petro/Chem catalog . . . details Teflon packings for valves, pumps, cylinders, and mixers. Packings are suitable for use on any fluid or gas to 450 F. *Halogen Insulator & Seal Corp.*

Circle number (71) on reply card.

Petroleum dyes . . . are described in booklet that tells of colors and types available, applications, sales value. *E. I. du Pont de Nemours & Co.*

Circle number (72) on reply card.

Pioneer 1008 vapor seal . . . a mastic protective coating for corrosion protection . . . is explained in new bulletin. *Witco Chemical Company, Inc.*

Circle number (73) on reply card.

Plastics table of properties . . . shows significant physical, electrical, chemical, and optical properties of nine thermoplastic materials. Data, compiled from test reports submitted by manufacturers, covers acrylics, acetate, butyrate, Teflon, and Kel-F fluorocarbons, nylon, polyethylene, and vinyls. *Cadillac Plastic & Chemical Co.*

Circle number (74) on reply card.

Plugaroo . . . is combination non-lubricated plug and check valve. As a check, the clapper — hinged on a 20-deg angle — seals under its own weight. As a plug, a quarter turn gives a positive seal without galling or scoring plug, clapper, or valve body. Available with Teflon or synthetic rubber seals in steel, semi-steel, or aluminum bronze from Series 15 to 90, and in sizes from 1 to 36 in. *Frank Wheatley Pumps & Valves.*

Circle number (75) on reply card.

Poxyglas tanks . . . can handle more than 200 corrosive chemical compounds. Corrosion-resistance chart, available on request, will show if they are suitable for your needs. Tanks are constructed of continuous glass filaments impregnated with epoxy resin and wound under tension over a mandrel in a calculated, controlled pattern for maximum strength and consistent quality. *Black, Sivalls & Bryson.*

Circle number (76) on reply card.

Proportioning pump . . . new 300 series . . . can be adjusted while pump is running. Has new control mechanism in which output of two cams are combined to vary the stroke of zero to maximum. Simplex model has capacity from 1 to 812 gal per hr. Duplex model capacity ranges from 2 to 1624 gal per hr. Maximum working pressure is 10,000 psi. *American Meter Pump Division.*

Circle number (77) on reply card.

PETROLEUM PROCESSING PETROLEUM PROCESSING PETROLEUM PROCESSING PETROLEUM PROCESSING PETROLEUM PROCESSING PETRO

WHY PETROLEUM PROCESSORS ARE BEGINNING TO GENERATE THEIR OWN GAS SUPPLY

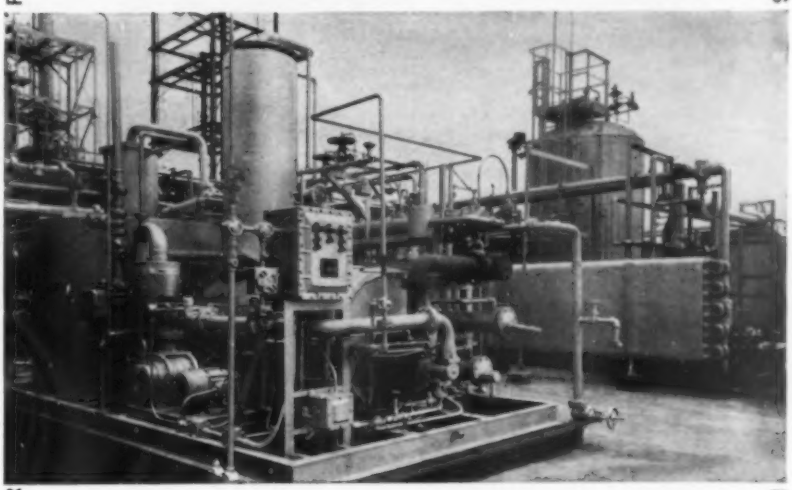
The new "packaged" type generator developed by Gas Atmospheres engineers, that drastically reduces gas costs even for minimum users, is a big reason why more petroleum processors are generating their own gas.

INCREASED USE OF GAS, too, is a factor. The more gas required the greater the savings. Instead of an "incidental" it becomes a major area of cost reduction.

FACTORY-TESTED SYSTEMS that come completely assembled can be put "on line" in a fraction of the time formerly required. No job-site construction is required.

STEP UP IN UNIT SERVICE provided by Gas Atmospheres' Service Department to cut down time to an absolute minimum on any make of generator is another reason why generators are selling better in the petroleum industry.

Texaco, Inc. uses this 10,000 cfh nitrogen/carbon dioxide Gas Atmospheres generator in the production of oil additives. A new 20,000 chf unit was recently delivered.



PACKAGED GAS SYSTEMS are designed and built for the production of nitrogen, carbon dioxide, hydrogen, inert, reducing and annealing gases, as are complete drying and purification systems, by *Gas Atmospheres, Inc., 3855 West 150th Street, Cleveland 11, Ohio.*

gas Atmospheres, inc

PETROLEUM PROCESSING PETROLEUM PROCESSING PETROLEUM PROCESSING PETROLEUM PROCESSING PETRO

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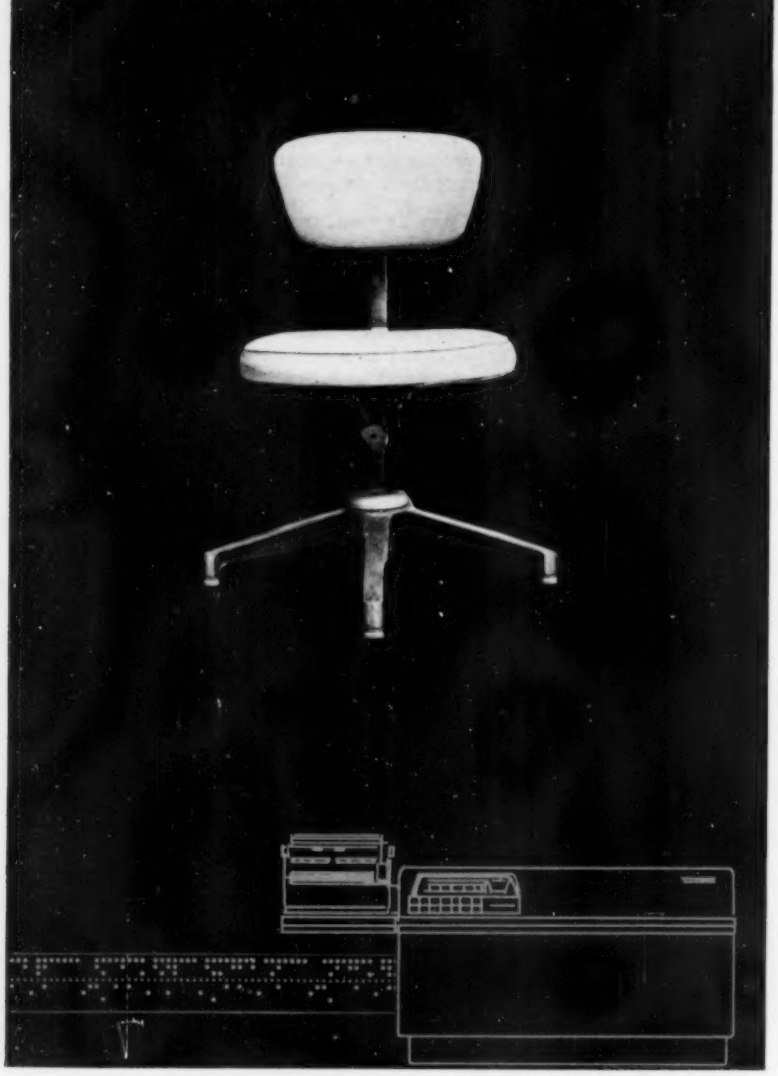

Knowing that the "slip stick" is not too far removed from the ancient abacus we have added a new dimension: electronic computation. Now in a fraction of the former time, and far more accurately, we can alternate all of the normal variables to develop the optimum cooler for your requirements. The combination of cooling "know how" and accurate automated engineering is just one more of the advancements that keeps Happy ahead.

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HAPPY

Pulsafeeder diaphragm gas compressor line . . . is designed to recycle, meter and compress gases for operation with absolute freedom from contamination. Will recycle gases at pressures up to 5000 psig, will meter with reproducible accuracy dependent on the varying intake and the discharge pressure, and will compress gases from atmosphere with better than a 10:1 compression ratio. *Lapp Insulator Co.*

Circle number (78) on reply card.

Pyrex "double-tough" drainline . . . for disposal of chemical wastes . . . is subject of 16-page catalog that gives full details on available fittings. *Corning Glass Works.*

Circle number (79) on reply card.

Recording pneumatic controller . . . Series 532 . . . may be used with any of manufacturer's standard measuring elements for control of pressure, temperature, flow, humidity, or differential liquid level. Available with choice of four modes of control. Has good frequency response (essentially flat to over 300 cycles per min), low air consumption (less than 0.1 std cu ft per min), high exhausting capacity (well over 3 std cu ft per min at 1 psi drop), high tolerance to shock, and high temperature stability. *The Bristol Co.*

Circle number (80) on reply card.

Remote control pan/tilt operation of closed-circuit television cameras . . . is vastly improved with Model ARC-14C weatherproof and Model ARC-14CX explosion-proof pan/tilt units. First unit can be used for training a TV camera in azimuth and elevation from a control center which may be up to 1000 ft away. The latter model is identical except for the additional quality of being explosion-proof for operation in dangerous atmospheres. *Kin Tel Div., Cohu Electronics, Inc.*

Circle number (121) on reply card.

Rol-Ruler . . . has a lot of drafting and drawing uses. A helpful gadget for drawing horizontal and vertical parallel lines, squares, quadrants, circles and arcs, cross-hatching. *Rol-Ruler Co.*

Circle number (122) on reply card.

Rotameters and system of interchangeable accessories that increase rotameter utility . . . are illustrated in compact new catalog. *Brooks Instrument Company, Inc.*

Circle number (123) on reply card.

Special coatings for lubricated plug valves . . . solve many corrosion problems that used to require special alloy valves. K-51 (Penton) plastic coatings give iron or steel valves exceptional resistance from attack by most acids, caustics, and solvents; Kanigen (metallic nickel) coatings assure corrosion resistance of nickel or stainless steel, and Teflon coated plugs assist lubricant efficiency on services where inadequate or infrequent lubrication is anticipated. *Rockwell Manufacturing Co.*

Circle number (124) on reply card.

Super Dempster-Dumpmaster . . . new self-loading packer . . . has been developed to collect refuse from existing Dempster-Dumpster containers. Consists of a pair of powerful truck-mounted clearance arms which empty the containers into the hopper opening of a 30

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Valcor's solenoid valves of Teflon are perfect for a wide variety of chemical processes requiring **absolute freedom from contamination!** The molded body and diaphragm of Teflon is chemically inert and **corrosion-resistant to virtually every medium.** Valcor solenoid valves outlast and outperform steel! Available in hundreds of sizes and pressure ratings . . . immediate delivery. Write today for free 16-page booklet telling how to select solenoid valves for over 500 corrosive media!

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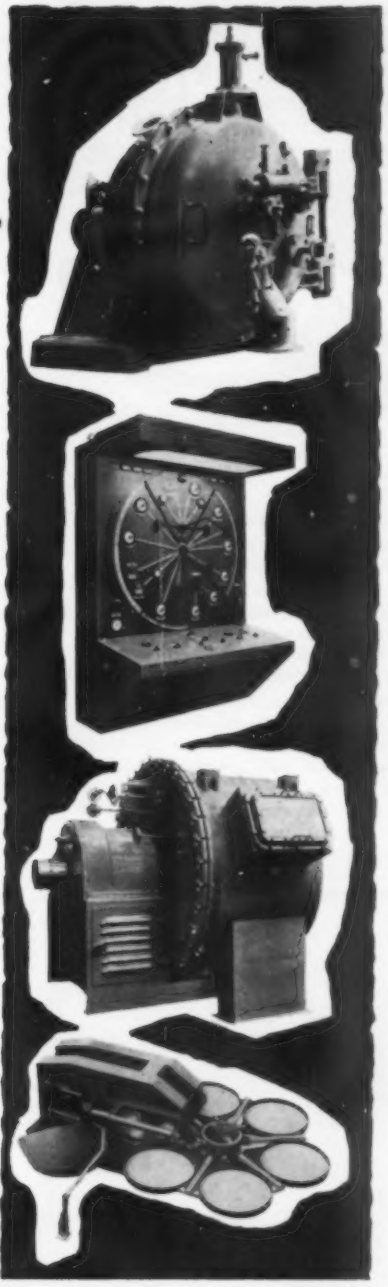

Pressure-tight peeler centrifuge

Electrical control

Pressure-tight filter

Plane-type press filter for 20 atm.

KRAUSS-MAFFEI—IMPERIAL
MUNCHEN-GERMANY

FILTERS
CENTRIFUGES
DRYERS
PULP MILL EQUIPMENT

For Speediest Repair of Corrosion Leaks in Pipe

JUNIOR

EMERGENCY PIPE CLAMP

Repair pipe leaks QUICKLY!

Speediest application — slotted lug permits the single plated bolt to slide instantly into place.

A companion to the old reliable Emergency Pipe Clamp that has served industry for a half century, the JUNIOR, a single bolt clamp, is 2⅞" wide. Undersells most band-type clamps.

Made of malleable iron, ruggedly proportioned, with full-length hinge along one side. Formed to exact pipe size—no bending. The recessed pressure-equalizing gasket, entire width of clamp, is cemented in. A lasting installation. 2" pipe size—$1.80; 2½"—$2.20; 3"—$2.30. Write for new circular on the Junior.

SKINNER-SEAL

EMERGENCY PIPE CLAMPS for safe, sure lasting repair of splits and rust holes in pipe. No pressure too high. Anyone can apply in a few moments. Made in all sizes, ½" to 12", for steel and C. I. pipe. Stocked by practically all oil supply stores.

Send for catalog!

M. B. SKINNER CO.
SOUTH BEND 21, INDIANA

cu yd compaction body, where the material is reduced to a fraction of its former volume by action of the 85,000-lb thrust developed by the hydraulic packer plate. *Dempster Brothers, Inc.*

Circle number (125) on reply card.

Teflon parts . . . extend use of Rockwood Sprinkler Co.'s ball valves to include corrosive chemicals and gases and fluids at temperature extremes from -40 to 350 F. Teflon or synthetic rubber is used in the following valve parts, depending on the application: valve seats, thrust washer, sealing gaskets, and packing rings. Valves are leak-proof and durable, and require no lubrication. *Raybestos-Manhattan, Inc.*

Circle number (126) on reply card.

Unusual or dangerous operating trends in a process plant . . . are detected automatically by an instrument-scanning subsystem of the RW-300 digital control computer, without interrupting the computer's control calculations. In effect, this permits the RW-300 to function as two machines — a control computer and an instrument alarm scanner. When an out-of-limit instrument reading is detected, the computer immediately notifies the operator and initiates the control action necessary to restore normal operating conditions. *TRW Computers Co.*

Circle number (127) on reply card.

Vari-Flo liquid blending systems . . . are subject of Bulletin 650. Equipment is designed for applications involving total flow rates between 1 and 2000 gal per min, with larger systems possible by adding more components. *Blackmer Pump Co.*

Circle number (128) on reply card.

Wire cloth information . . . is supplied in folder that gives details on selecting and ordering. *Newark Wire Cloth Co.*

Circle number (129) on reply card.

Xactpak thermocouple wire and accessories . . . are described in new 12-page catalog. *Claud S. Gordon Co.*

Circle number (130) on reply card.

X-Seal rings . . . combine characteristics of rubber O-rings with physical properties of teflon. Named because of their X-shaped cross-section, these cup-type seal rings were designed to provide more resilience, to eliminate the close tolerances required with teflon O-rings, and to permit installation with either slight or moderate seal contact pressure or interference. Supplied in the range of 0.114 in. ID to 4.475 in. ID. *Allegheny Plastics, Inc.*

Circle number (131) on reply card.

CLOSE OUT — CHEMICAL PLANT AT ORANGE, TEXAS

Type 316 stainless steel tanks, kettles, heat exchangers, columns, stills, crystallizers, centrifugals, pumps, valves, etc.

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SEND FOR LIST

PERRY EQUIPMENT CORP.
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5,000 psi

MERCOID PRESSURE CONTROLS

OPERATING RANGE
500 to 5,000 psi.

External Adjustment
Sealed mercury contact
Visible calibrated dial
Visible on-off circuit
Repetitive trip point

TYPES AVAILABLE

DXA-21
minimum differential 450 psi.
DXA-521
minimum differential 200 psi.
DXS-221
minimum differential 150 psi.

Available in three case styles;
General Purpose
Weather-Proof
Explosion-Proof

WRITE FOR BULLETIN O-21

THE MERCOID CORPORATION
4205 BELMONT AVENUE
CHICAGO 41, ILL.

PIPELINE Engineer

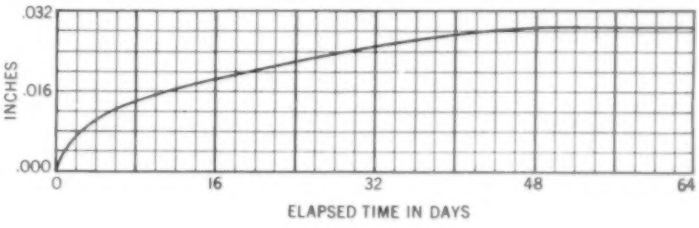
Engineering and Operating Section

NEWS FROM DOWN THE LINE!

Are all pipeline insulators as alike as two peas in a pod?

They're not alike, not in physical properties! When plastic insulators first became available for pipeline use, WmSON felt they were inferior to the steel and block types then available. We delayed our entry into the field until we could provide a plastic material to withstand field abuse and wear. We found that material in a high density polyethylene which could be injection molded to provide low cost insulators of the highest quality.

Our decision has proved sound. Breakage and excessive wear of glass fibre reinforced plastics, particularly in large sizes, has created a lack of confidence in plastics in general, but the M-2 Plastic THINsulator® has proved its stamina. Its high resistance to cold flow has been proved. Deflection test results: 1000 p.s.i. on each THINsulator runner for 64 days — total cumulative deflection only 0.029". Max. temp. during test, 105° F., min. temp., 75° F.



Its low coefficient of friction causes it to slide easily inside casing. The M-2 is completely resistant to impact fracture (4.0 ft. lbs./in. notched) and has successfully worked on 36" pipe, ½" wall, pulled in excess of 500 feet. We are convinced that it will perform as well or better than any other insulator on the market, including all known steel types. Other physical properties: *Dielectric strength* — (short time, ⅛" thickness) 500 volts per .001 inches (D149-55T); *Tensile strength* — 4400 p.s.i. at 20 in./min.; *Elongation* — 25% 20 in./min.; *Abrasion resistance* — Taber index 5.7.

The increased acceptance of the M-2 THINsulator has brought production to a level of real economy in injection molding. These cost savings are being reflected in new WmSON prices for 1961.

In planning '61 cased crossings, don't pay a premium for other insulators — use WmSON engineered M-2's and save!

T.D. Williamson, Inc.

P. O. BOX 40 • TULSA 2, OKLAHOMA

REPRESENTATIVES AROUND THE WORLD

how to keep metal away from petroleum...

UNICOR®

..and why it pays, in terms of both product and equipment!

Petroleum products and metals are apt to wage war. Life-robbing corrosion attacks the metal, while profit-stealing contamination downgrades the product. But there's an easy way to forestall such trouble. Use UNICOR.

This potent, film-forming, oil-soluble corrosion inhibitor plates out on metal, stands off corrosion by crude or refined petroleum. Only 10 to 20 parts of UNICOR per million of product assures lasting protection against corrosion in pipelines, refinery vessels and tanks.

Purer product, longer equipment life, reduced downtime for maintenance and cleaning, lower power costs . . . all result from using UNICOR. For detailed information and samples write our Products Department.

See our PSE *

Correct selection and most effective use of petroleum inhibitor and additives involves expert analysis and consideration of many factors. As specialists for over a quarter-century, UOP is able to provide unparalleled field service, brought to you by a member of our staff of *Product Sales Engineers. For detailed information on the UOP family of superior inhibitors and additives call or write our Products Department.

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WHERE RESEARCH TODAY
MEANS PROGRESS TOMORROW

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

SHAPING THE FUTURE . . . *in Pipelining*

API DIVISION OF TRANSPORTATION has been cooperating with the Corps of Engineers on a military pipeline study, at the request of the U. S. Defense Department. Construction methods on both welded and coupled pipelines were under consideration, out of which will come recommended practices for applicability in "Theaters of Operations." Services of a number of engineers were made available by operating companies, on a rotating basis, for a period of two months.

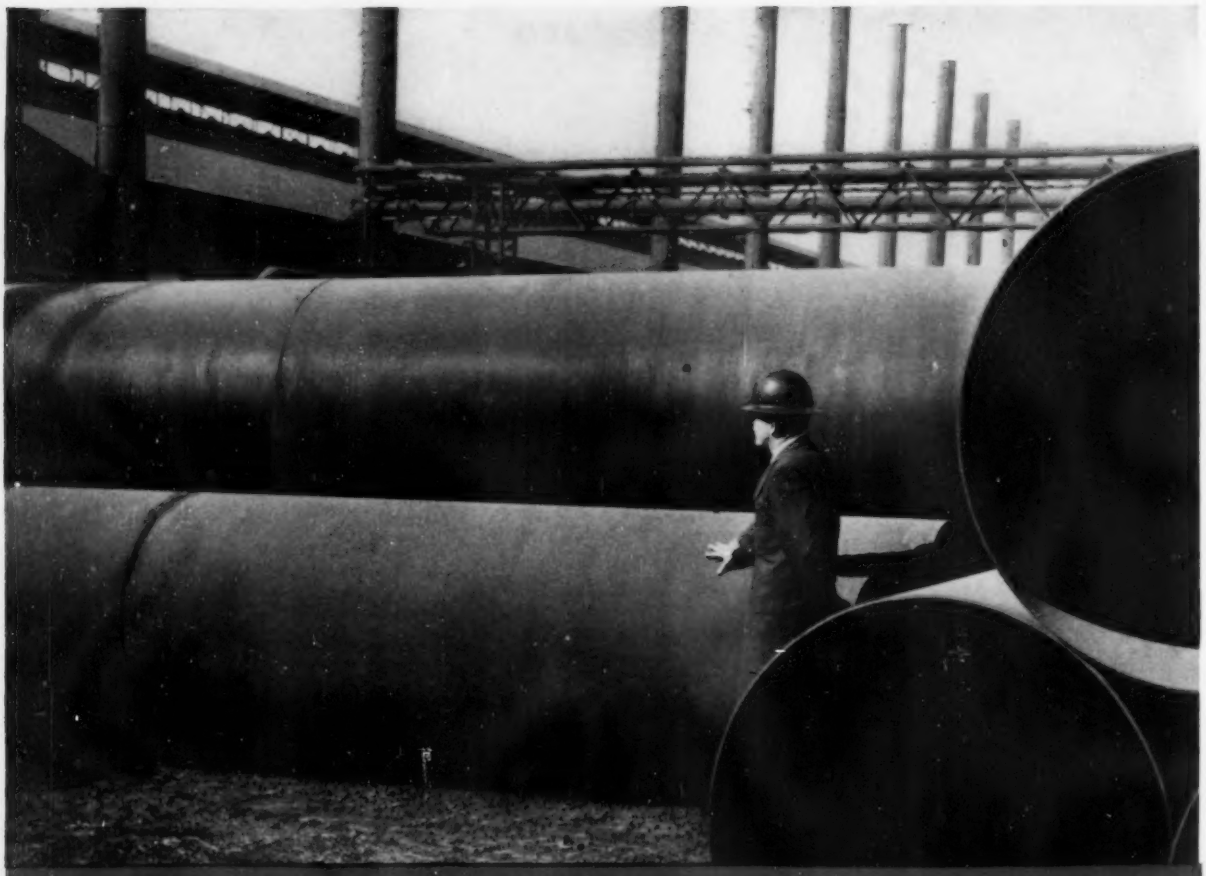
NATURAL GAS RESERVES in the U. S. totaled 263.7 trillion cu ft at the beginning of the year, an increase of 1.1 trillion cu ft over the previous year despite consumption of 13 trillion cu ft in 1960, according to the annual AGA-API joint report. Reserves of natural gas liquids were 6.8 billion bbl, an increase of 294 million bbl over 1959.

CANADIAN GAS RESERVES rose to 30.6 trillion cu ft compared with a previous peak in 1959 of 26.6 trillion cu ft, the annual report of the Canadian Petroleum Association shows. Production in 1960 was 539.5 billion cu ft, up sharply from 498 billion cu ft for 1959.

INDUSTRY'S FIGHT for a liberal policy on microwave usage seems won, for the time being at least. The American Rocket Society has moved for dismissal of its petition before the U. S. Court of Appeals asking review of an FCC decision which denied a request that certain high frequencies be dedicated to space communications. Had FCC been reversed in its stand, the operational fixed microwave frequencies used by the pipeline industry (and petroleum industry generally) would be in jeopardy.

AIDS FOR THE COMMUNICATIONS MAN: A new development condenses a voice by ignoring redundant sounds in speech and transmits only those sounds needed to make speech intelligible. Could substantially reduce radio bandwidths needed for speech transmission. Another development is a "scrambler" device for mobile radio. Should appeal, whether as a matter of security or simply a desire for privacy.

ADVANCEMENTS IN COAL PIPELINING are reported nearing the operational stage. Consolidation Coal Company has developed a "stabilized slurry" that can be stored like heavy fuel oil and eliminates the need for much of the present costly processing equipment. A centrifuge developed by Combustion Engineering prepares the slurry for almost immediate burning.



Dearclad® 765 proves again: It's fast, it's tough, it's economical; It's the epoxy that's really right!

Dearborn's 765 Dearclad epoxy coating was specified for the 2,000 feet of 42 and 48 inch water main at U. S. Steel's South Works at South Chicago. This pipe was coated by an applicator and then delivered and stacked for several weeks at the job site, prior to installation. Conditions and terrain were such that part of the line was laid above ground subject to attack by corrosive atmosphere and part below in very corrosive fill. On the job, Dearclad epoxy was cold applied to welded joints and miter cut bends. Coating thickness throughout averaged 15 to 20 mils.

Dearclad 765, a coal tar modified epoxy—developed in Dearborn's research laboratories—shows extraordinary resistance to impact, abrasion, handling damage, and chemical attack. It has a rapid curing rate . . . is effective through temperatures from −40° F. to 250° F.+ . . . has positive storage stability with no sag and no cold flow . . . can be applied by brush, roller, or spray.

NO OTHER PRODUCT ON THE MARKET COMBINES ALL THE DESIRABLE PROPERTIES OF DEARCLAD 765. YET ITS COSTS ARE COMPARABLE TO OLD STYLE, LESS EFFECTIVE COATINGS.

It will pay you to check with a Dearborn engineer before your next coating job. Or write today for Technical Bulletins.

pioneer in the science of corrosion control

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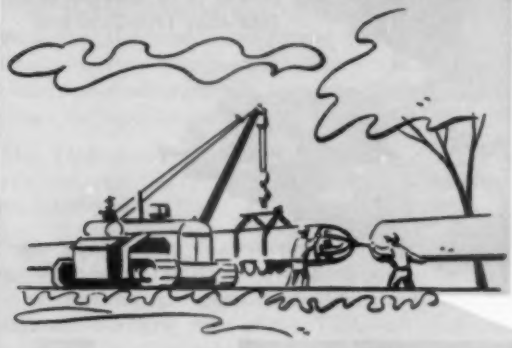
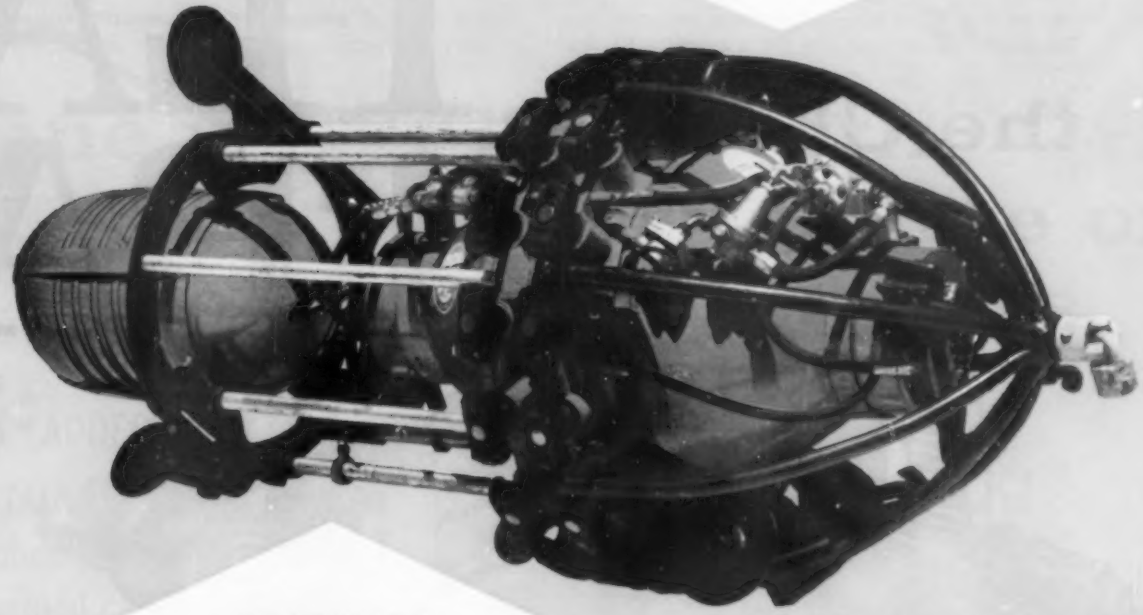
NOW CROSE-PERRAULT

PRESENTS THE FINEST, MOST POWERFUL

INTERNAL LINE-UP CLAMP

IN THE PIPELINE INDUSTRY





FEATURES:

- most powerful in the industry
- lighter weight
- faster retraction
- easier to pull through pipe
- has large diameter, ball bearing wheels for easier and faster movement of clamp
- plastic wheels furnished for internally coated pipe
- double-acting cylinders
- available with double rollers or conventional studs
- 20" to 36" pipe sizes
- self-propelled model available on request

CROSE-PERRAULT LINE-UP CLAMPS HAVE LINED UP MORE MILES OF PIPE THAN ALL OTHERS COMBINED.

Crose-Perrault engineers have worked for years to keep improving the features of these clamps — now you can have the best clamp ever designed with features that mean faster and easier line-up.

Crose perrault
EQUIPMENT CORP

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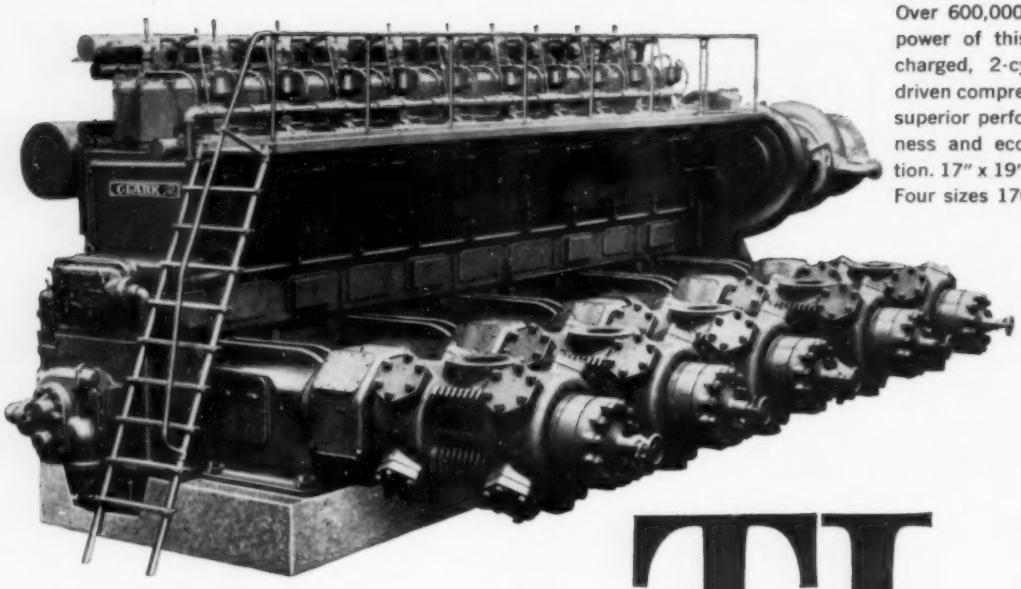
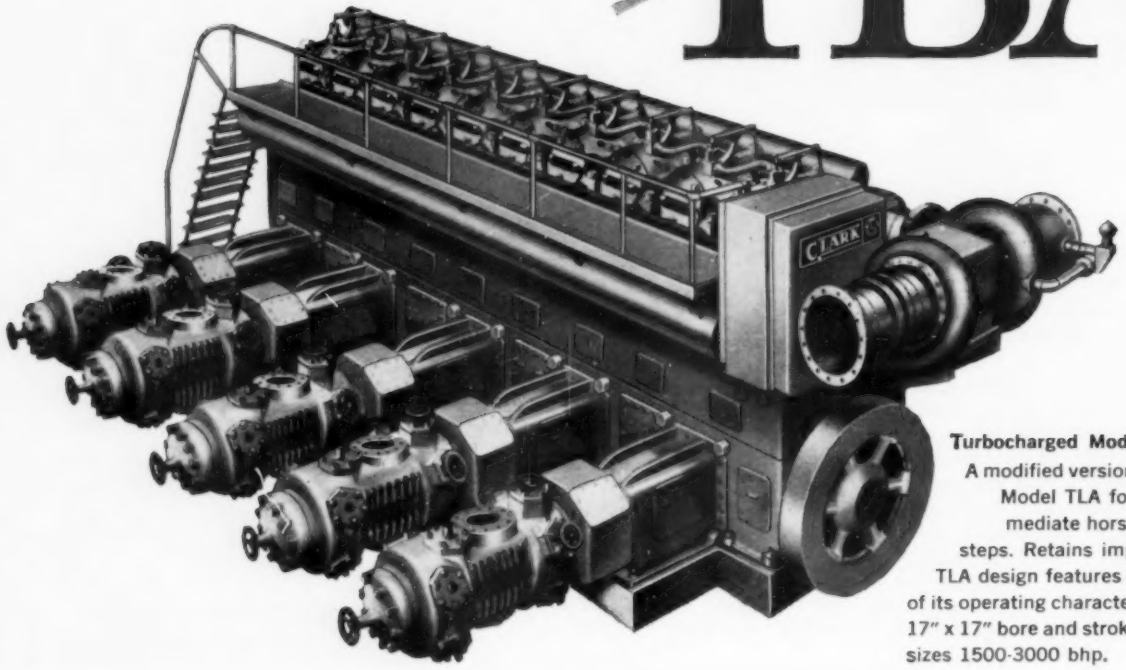


Popular Model TLA
Over 600,000 installed horsepower of this famous turbocharged, 2-cycle gas-engine-driven compressor testify to its superior performance, ruggedness and economy of operation. 17" x 19" bore and stroke. Four sizes 1700-3400 bhp.

the CLARK TLA TBA



Turbocharged Model TBA
A modified version of the Model TLA for intermediate horsepower steps. Retains important TLA design features and all of its operating characteristics. 17" x 17" bore and stroke. Four sizes 1500-3000 bhp.

FOR FURTHER INFORMATION ON
ADVERTISED PRODUCTS, SEE READER SERVICE CARD

Now you can name the horsepower—from 1500 to 3400 bhp—and name Clark with confidence. Clark has the compressor to fit your needs *exactly!*

With the addition of the TBA Series (a modified version of the time-tested Model TLA 2-Cycle, Gas-Engine-Driven Compressor), Clark now offers eight closely graduated sizes in this important horsepower range for pipeline and process applications.

The TBA is carefully matched to the TLA, giving you not only the best horsepower choice, but also a machine you can trust. Here's how it's done:

Same Heavy Duty Construction—The TBA incorporates the lower crankcase with thru-bolts, crankshaft, power pistons, compressor cylinders, aluminum bearings and running gear of the TLA—all thoroughly proved in exacting field duty. Both machines are specifically designed to handle the high power delivered by turbocharging.

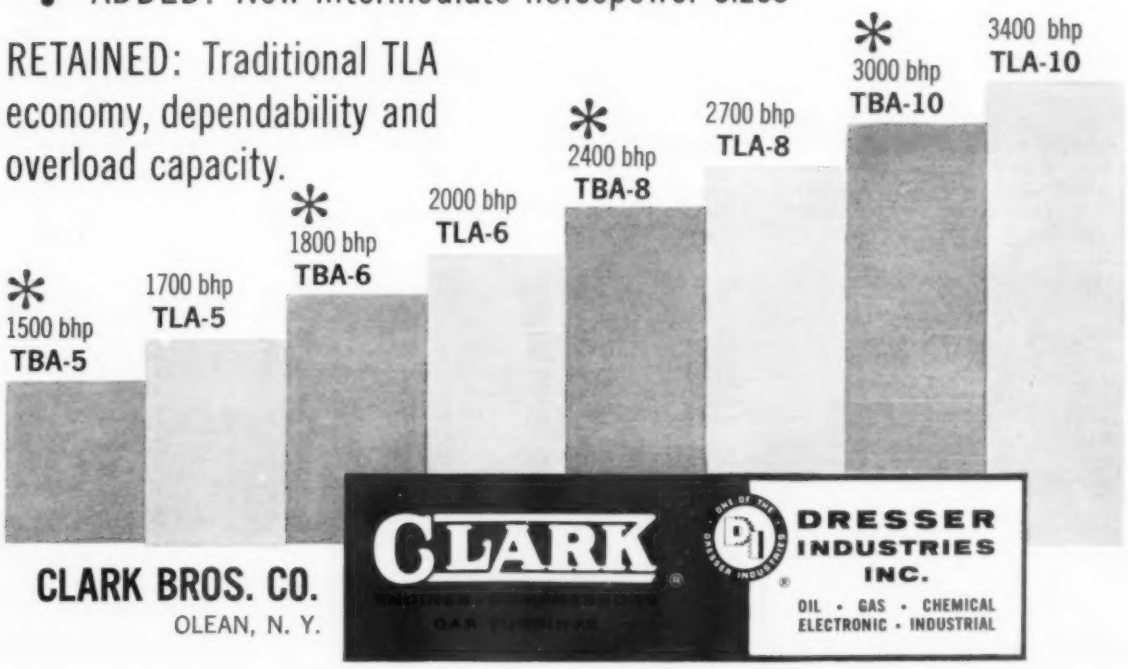
Same High Efficiency Turbocharging System—The Clark designed, constant pressure turbocharger provides a flexible supply of combustion air that varies in proportion to the load placed on the engine. Thus the fuel-air ratio is inherently correct over the entire operating range.

Same Operating Flexibility—The turbocharger system coupled with a new automatic ignition timing control makes the TBA and the TLA ideally suited for variable speed, variable load applications. The fuel consumption curve remains essentially flat over a wide range . . . from reduced speeds at constant or variable torque all the way up to substantial emergency overloads at rated speed.

What's different, then? The stroke on the TBA has been shortened from 19″ to 17″, the external configuration of the power cylinders has been modified, and the ratings have been changed in accordance with the new stroke length. The TBA is built in five, six, eight and ten power cylinder models rated at 1500, 1800, 2400 and 3000 bhp respectively.

More facts are yours for the asking. Write for new Clark TBA Bulletin 206, and new TLA Bulletin 225.

Line is IN STEP with your pipeline or process requirements


* ADDED: New intermediate horsepower sizes
RETAINED: Traditional TLA economy, dependability and overload capacity.
* 1500 bhp TBA-5
1700 bhp TLA-5
* 1800 bhp TBA-6
2000 bhp TLA-6
* 2400 bhp TBA-8
2700 bhp TLA-8
* 3000 bhp TBA-10
3400 bhp TLA-10

CLARK BROS. CO.
OLEAN, N. Y.

CLARK

DRESSER INDUSTRIES INC.
OIL • GAS • CHEMICAL
ELECTRONIC • INDUSTRIAL

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

BECHTEL'S NEW 777 DITCHER HIGHBALLS MIDDLE WEST LINES AT 10,000-FT. IN 12 HOURS

Up to 1000′ per hour recorded on 54″ x 7′ ditch while sloping up to 9′ wide; 8½′ digging depth eliminated 40% of backhoe work on hillsides and road crossings.

The new Barber-Greene Model 777 is setting production records wherever it is working. Field reports show 10,000-ft. of 54″ x 7′ trench in a 12-hour day. Pipeline crews have enthusiastically welcomed the 777's 8½′ digging depth and the resulting sharp reduction in backhoe work on hills and at crossings.

This new Barber-Greene pipeline ditcher digs up to 40% faster, weighs 37% more, has 40% more power and digs one foot deeper, than any other full-crawler pipeline wheel ditcher. Exclusive Hydra-Crowd transmission lets operator dial the precise speed to match ground conditions – keeps maximum machine power applied to the job at all times.

Standout specifications: 135 hp diesel power; digs 8′6″ deep and 54″ wide trench (to more than 10′ at trench top with slopers); weighs 57000#; exclusive dual-range Hydra-Crowd puts infinite number of crowding speeds from zero to 66 fpm at operator's fingertips; hydraulically driven spoil conveyor, crowding, transmission wheel speeds and wheel hoist are completely independent of each other; belt speeds infinitely variable to 1,000 fpm; three-point suspension; flexible drawbar; and digging wheel mechanically driven by short drive chains and split drive shaft.

Write for new 777 Bulletin, specifications and comparisons.

LOWBOY PORTABLE—The Model 777 is the only wheel ditcher of its digging range that can be transported by lowboy trailer with no disassembly. Unloads ready to dig ditch.

Barber-Greene Ditcher Line A Complete Pipeliner's Package

MODEL 774 with 5½′ wheel cuts from 18-30″ wide. Can be equipped with 7′ wheel for 50% less than any other wheel ditcher with this depth capacity.

MODEL 773 trenches 10-24″ wide and to 5½′ depths. Model 772 identical except for narrower track gauge and pad widths. Works within 19″ of side obstructions.

MODEL 784 heads Barber-Greene Vertical Boom Ditcher Line. Machines utilize same chassis as Model 774, cuts low cost trench from 18-24″ wide and to 7′ deep.

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

BECHTEL CORPORATION'S first assignment for their new Barber-Greene Model 777 was 102 miles of trenching, covering virtually every kind of terrain in the Midwest.

MODEL 705-B RUN-ABOUT is an all-ground, all-weather Vertical Boom Ditcher with 16 mph road speed to handle the scattered jobs most profitably. Hydra-Crowd transmission provides infinite number of crowding speeds from 0 to 16 rpm.

Manufacturer of the only modern ditcher line.

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Other Plants: DeKalb, Milwaukee, Detroit, Canada, England, Brazil, Australia

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Need a meter or a pump? Need service? Man to see is your A. O. Smith sales representative. He knows his equipment inside and out . . . can match a meter or pump to your exact specifications. There are over *100* A. O. Smith "reps" listed on the map — one conveniently located near you for fast, dependable service.

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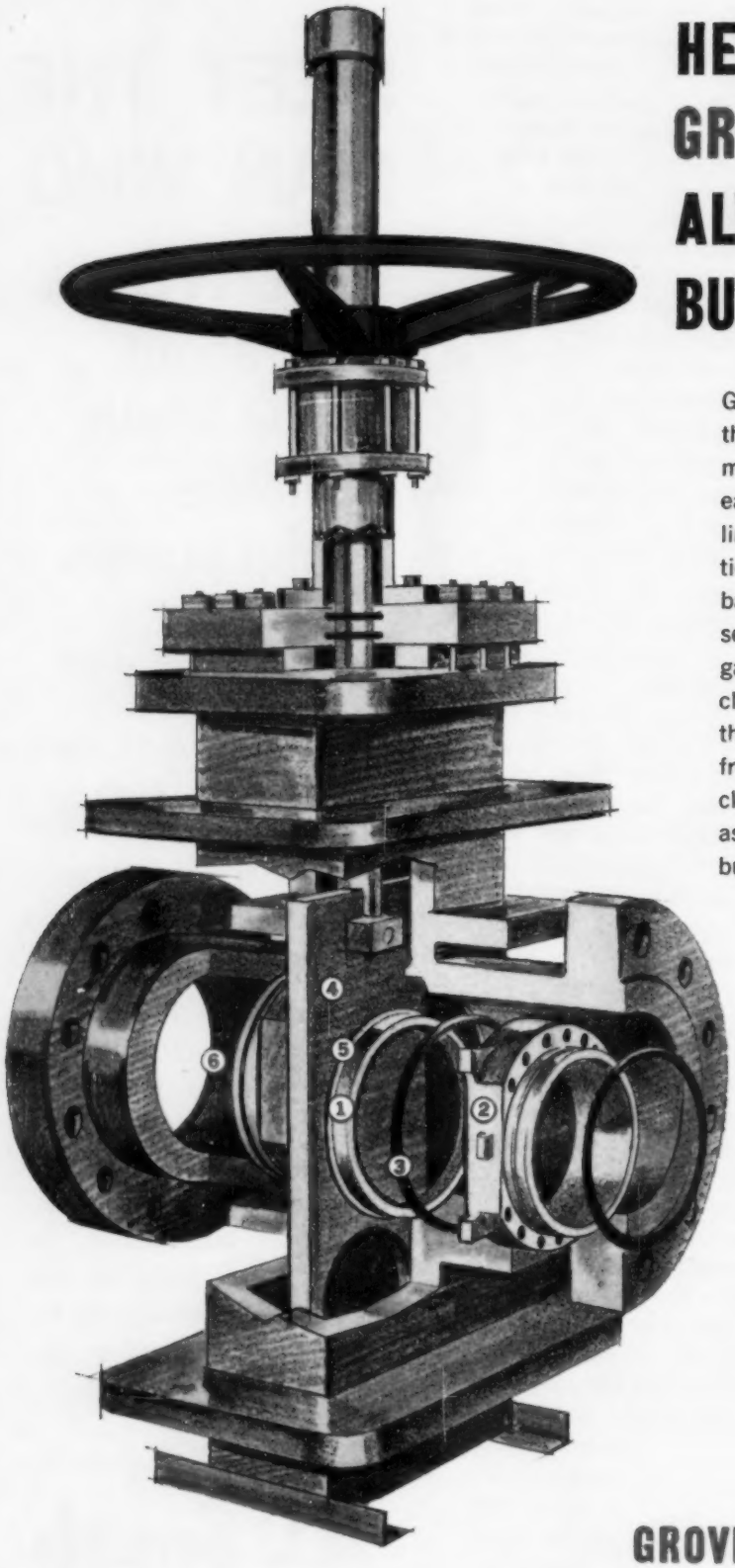

HERE'S WHY A GROVE G-4 VALVE ALWAYS GIVES A BUBBLE-TIGHT SEAL

Grove protected Seal-"O"-Ring® system is the heart of the G-4. Inner (1) and outer (2) metal seat rings shield the o-rings (3) on each side of the gate (4) from damage by line contaminates. Inner seat rings also function as a primary metal-to-metal seal (5) backed up by the o-rings. No lubricants or sealing compounds are needed. The floating gate and seats assure fast, easy opening and closing, and positive, bubble-tight sealing; the inner metal rings scrape foreign matter from the gate while the o-rings squeegee it clean. Through conduit (6) is provided to assure ideal flow characteristics. Send for bulletin #571.

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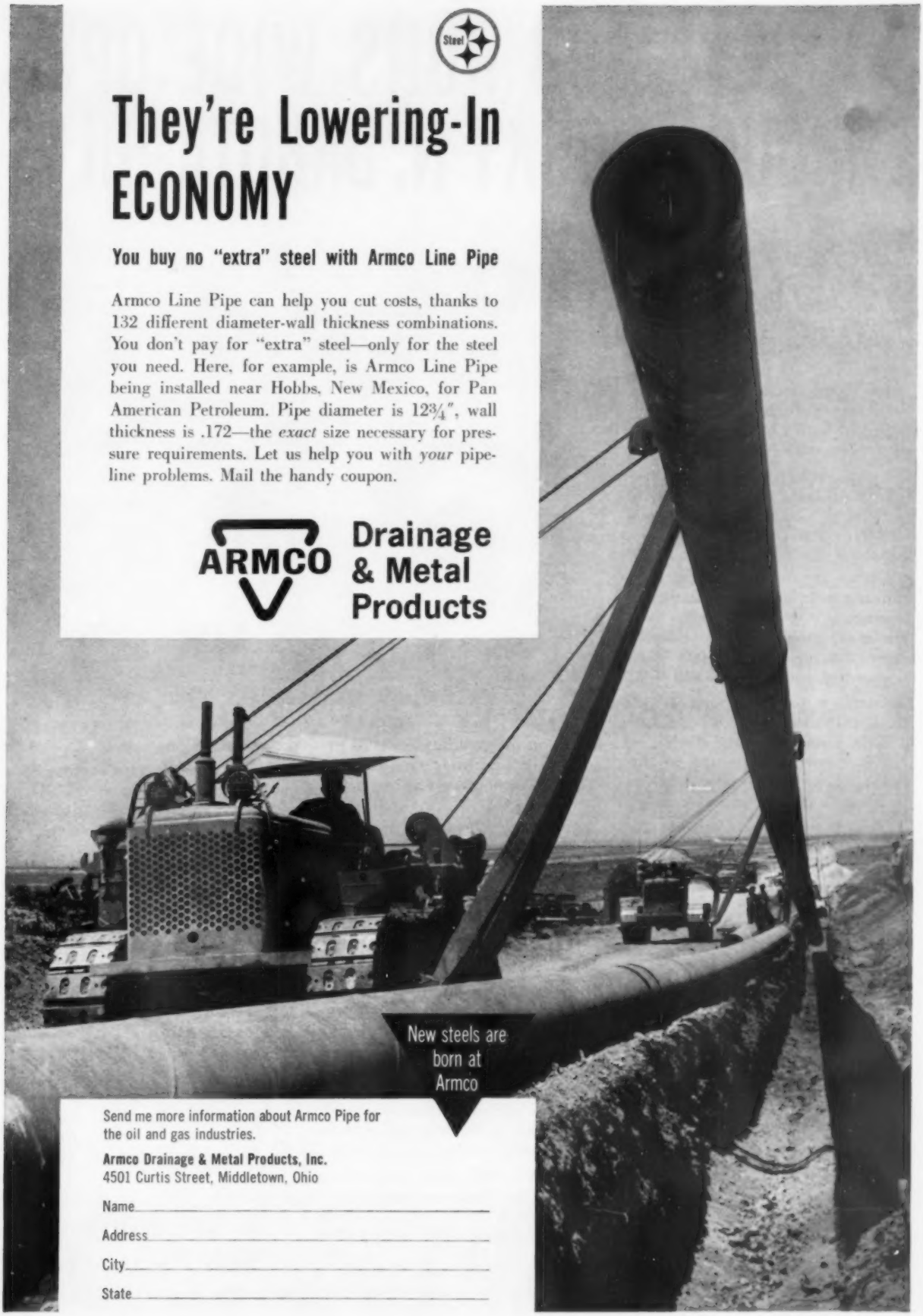

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BUCKEYE 308 RUNS WIDE OPEN THROUGH ROCKY N. DAKOTA HILLS

Ditcher Takes 45° Grades Without Tow Tractor

A Gar Wood-Buckeye 308 is cutting 6,000 feet of ditch per day through rock and hard clay in the foothills of northwestern North Dakota.

The job is a 55-mile, 10-inch pipeline being laid between Minot and Newburg. Contractor is Curran Construction Ltd. of Edmonton, Alberta, Canada.

Curran reports the 308 has been running wide open, and has ditched as much as 9,500 feet in a day. Even grades as steep as 45° haven't slowed down the sure-footed 308—a tow tractor has never been needed.

Curran's ditcher operator, Bill Rose, calls the Gar Wood-Buckeye 308 the finest all-around ditcher he has ever operated. Singled out for special praise by Rose: the 308's outstanding hydraulic conveyor drive.

This drive, with its three speeds in either direction, allows instantaneous, on-the-go adjustments of the spoil pile—without complicated shifting, without stopping crawlers or digging wheel. And the entire operation of the conveyor is controlled by simple levers located at the operator's fingertips.

Contractors across the country are getting more ditch for their dollars with Gar Wood-Buckeye ditchers. Your Gar Wood-Buckeye dealer can show you why.

GAR WOOD ENGINEERING MAKES BUCKEYES RUGGED ENOUGH TO RIP THROUGH ROCK

To meet fast production schedules through terrain as tough as North Dakota's, the Gar Wood-Buckeye 305, 307 and 308 ditchers are more than just "ruggedly built." They are scientifically engineered to resist stress, to cut vibration to a minimum, and to deliver the greatest useful power to the digging wheel.

An all-welded panel truss frame supports the digging wheel and conveyor assembly of these machines—is exceptionally rigid and resistant to stress. The wheel itself is formed of two steel rings welded together for far greater strength. And the unique Buckeye digging buckets are of two-piece construction for greater abrasion resistance and easier maintenance.

Exclusive features like these—the result of 68 years of ditcher engineering—make Gar Wood-Buckeye the *outstanding* choice in ditchers, no matter how tough the terrain.

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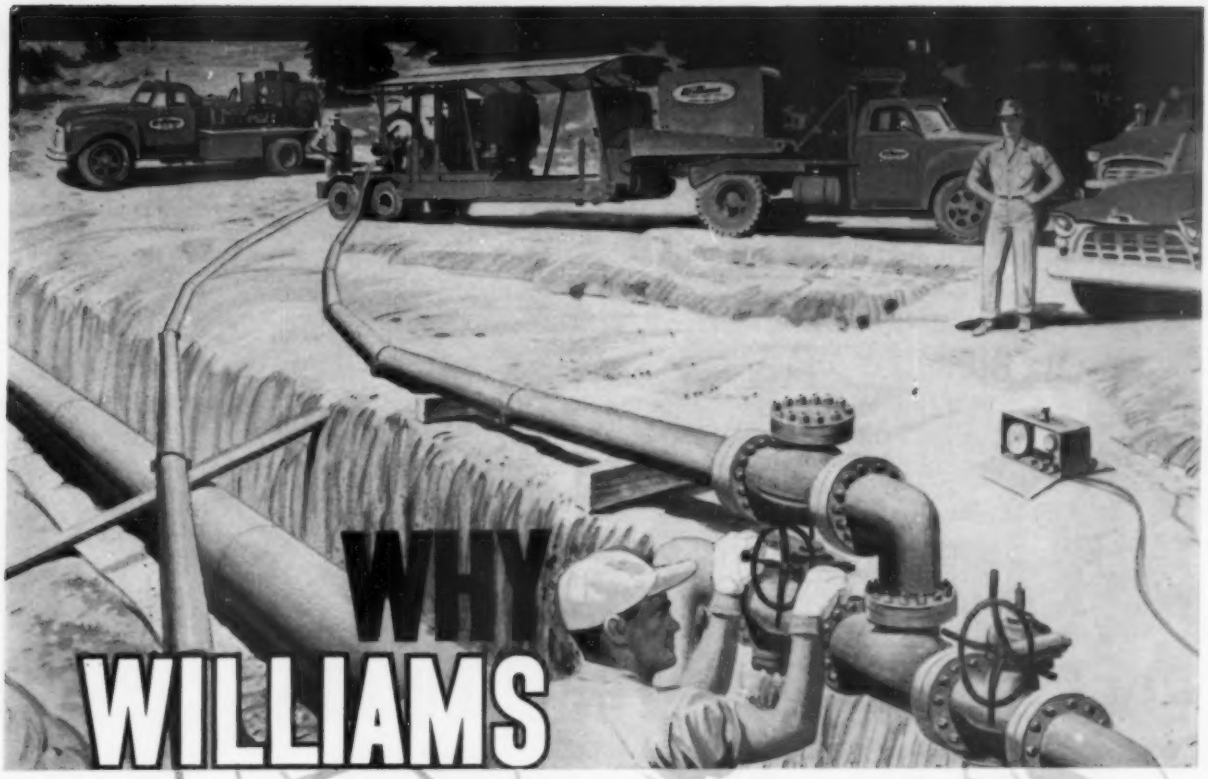

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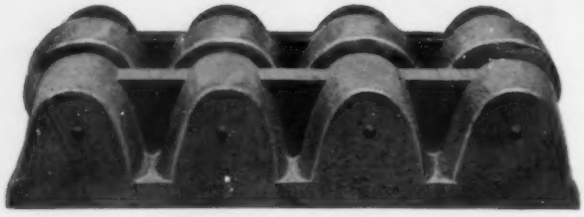
Single Greenhead "Go-Roll" staggered on neoprene backed metal band for pipe over 20"



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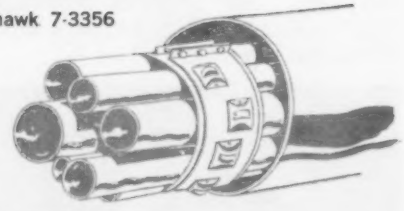

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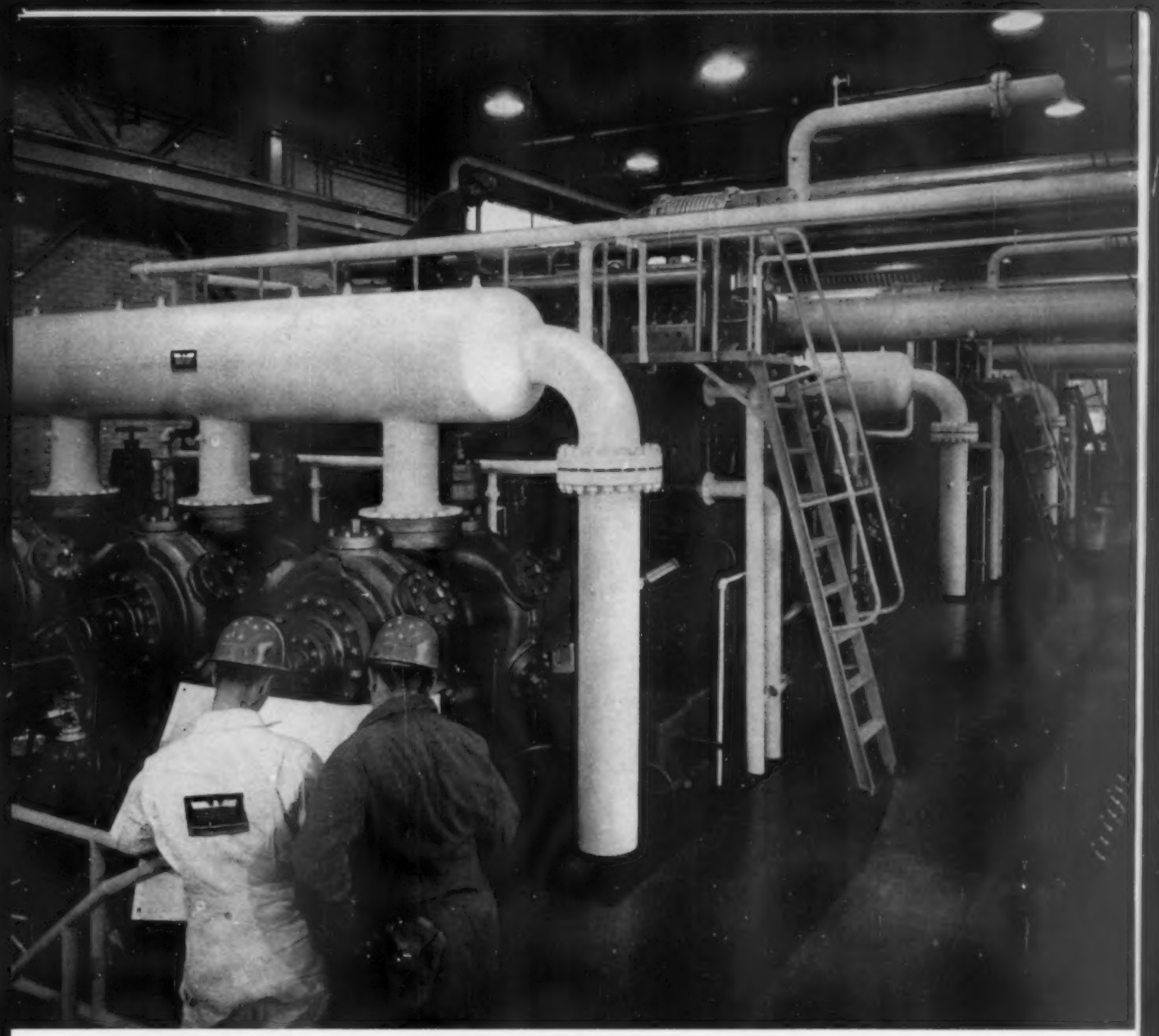

Trans-Canada Pipe Lines Limited Chooses Worthington SUTC's . . .

FOR FIRST FULL AUTOMATION

At central control, the dispatcher pushes a button. At the compressor station miles away, a solenoid throws an air valve. Engine and compressor cylinders begin purging . . .

At 6 seconds, ignition actuates, fuel is admitted and the engine slowly accelerates toward 160 rpm. At 20 seconds the compressor cylinders stop purging. In 5 minutes, the engine-compressor is ready to be brought on line.

This is a glimpse of normal operation of Trans-Canada Pipe Lines Limited's Maple Station—the first to be fully automated by this pipeline company. Three Worthington SUTC engine-compressors operate in pre-set sequences according to signals from the dispatcher who, though 25 miles away, could be a thousand.

These new SUTC's have a higher compression ratio for increased efficiency; improved handling of heat load through new computer-designed Turbo-Chargers; and new bearing construction. Cylinder parts and Double Deck valves were manufactured in Canada.

The station organization chart shows the benefit of these automated SUTC's. This station has no operators. This saves initial cost of four houses and salary and overhead for the operators.

For complete information on SUTC's for automated or conventional installations, call your nearest Worthington District Office. Or write Worthington Corporation, Dept. 43-22, Buffalo, New York. In Canada, Worthington (Canada) Ltd., Brantford, Ontario.

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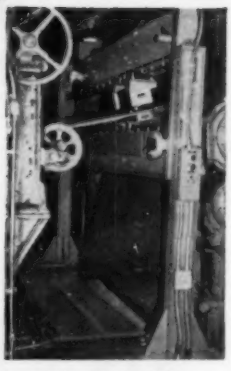

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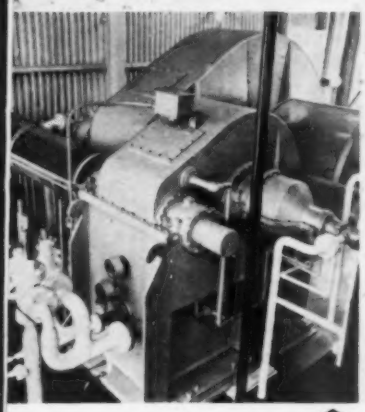
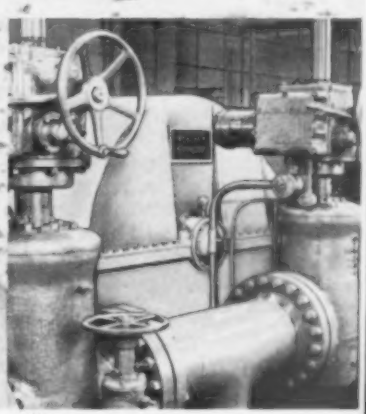
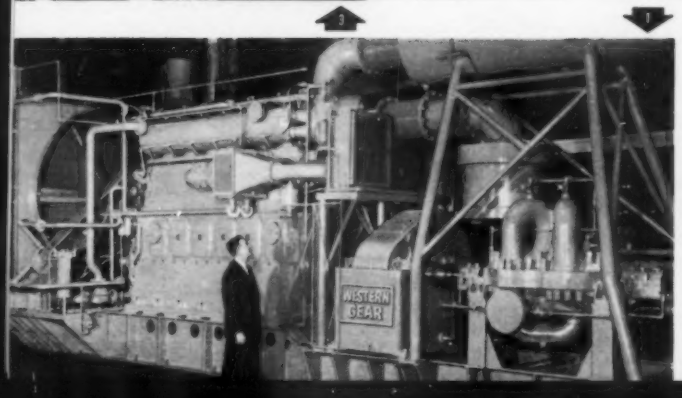
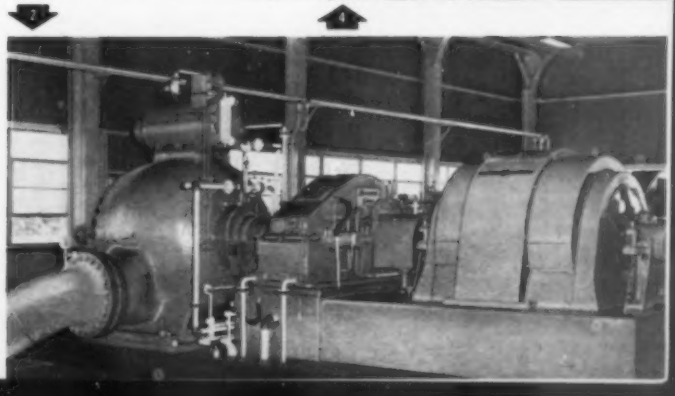


1. *Western Gear hi-speed unit boosts 600 RPM 925 HP at engine input to a 3550 RPM centrifugal pump at a pumping station of American Independent Oil Co. in Kuwait.*
2. *One of 2 Western Gear Model 300HS150 units installed for El Paso Natural Gas Company in its Leupp, Arizona station... 5750 HP from 1200 RPM electric motor to 8500 RPM centrifugal compressor.*
3. *One of 20 two-stage hi-speed drives which step up 5000 HP 327 RPM engines to centrifugal compressors at 6055 RPM for Columbia-Gulf.*
4. *Western Gear speed increasers like this are used exclusively on Mid-Valley's 1,000-mile pipeline. A total of nine 1200 HP 450/3600 RPM and seventeen 1700 HP 327/3600 RPM units are in service.*







WILLIAM A. GARRATT
Measurement Analyst
Transwestern Pipeline Company

Transwestern Makes On-the-Spot

Portable titrator takes less than 30 minutes to determine concentrations to the nearest 0.001 grain per 100 cu ft.

BECAUSE OF THE GAS quality clauses written into most gas sales contracts, imposing restrictions on tolerable concentrations of hydrogen sulfide and other sulfur derivatives, it logically follows that there is a need for instruments and methods to determine accurately these concentrations with a minimum of effort.

There are several acceptable laboratory methods for determining the sulfur content of gases, most of which are laborious and time consuming and require the utmost care in sample handling. In contrast, the equipment and methods employed by Transwestern Pipeline Company allows on-the-spot testing with little effort, all at a high degree of accuracy.

The equipment used by Transwestern to determine sulfur concentrations is a portable fast-acting analyzer manufactured by American Systems, Inc., affiliate of Schlumberger Well Surveying Corporation. This analyzer is a manually operated potentiometric electrolytic titrator, a development of Dr. Robert Austin of San Gabriel, California. It is appropriately named the Austin Gas Titrator.

The Austin titrator may be used by a proficient operator to determine concentrations of hydrogen sulfide, mercaptans, sulfides, and residual sulfur to the nearest 0.001 grain per 100 cu ft in less than 30 minutes. The portability features of the instrument lends itself to the conductance of routine wellhead tests and periodic tests at pipeline locations without provisions for sample containers. As Transwestern handles many sour gases, the Austin titrator has become an indispensable tool of the company's gas measurement and quality control personnel.

The practical aspects of the Austin titrator are self-evident to those confronted with many sulfur tests. Transwestern's confidence in the accuracy of the equipment was gained from tests of synthetically prepared samples mixed of pure components compared with the results obtained by other test methods.

Titrator Is Portable

As may be noted in Fig. 1, 2, and 3, the titrator is designed for convenient portability and is housed in a lightweight aluminum case. Operating components are fully accessible once the top of the case has been removed and the apparatus has been mounted on a tripod.

The instruments' controls are in a compact cluster on the right side of the tray panel (see Fig. 2). At the top of the panel is a wire lead with a plug-in connection for the titration cell. When not in use, this wire is plugged into an outlet on the panel labeled "battery check." When in this position the meter will indicate the condition of the battery.

Other controls are near the label "titration current" (Fig 2). The switch opens and closes the generating current circuit. The dial knob regulates the intensity of the generating current. The small button switch labeled "boost" is one that shunts the control and gives a momentary high generating current as an aid in rapidly bringing the bromine level to the desired value. The two other switches connect the meter to the generating circuit when depressed. The one labeled "check" reads within 0 to 2 milliampere range. The other, labeled "X5," extends the meter range to 10 milliamperes when both are depressed simultaneously.

Two titration cells with electrical connectors are provided along with the scrubbing cells. All cells have fritted glass bubblers to insure maximum gas-liquid contact. A polyethylene filter cell, filled with activated charcoal and molecular sieve, is included for the removal of all sulfur compounds from the gas in the determination of "bank" values. Bottles containing the various filtering and titration solutions are supplied, with the analysis of each solution shown on the bottle.

Bromine Solution Used

The Austin titrator was designed for use with both bromine and iodine solutions. Transwestern personnel, how-

FIG. 1

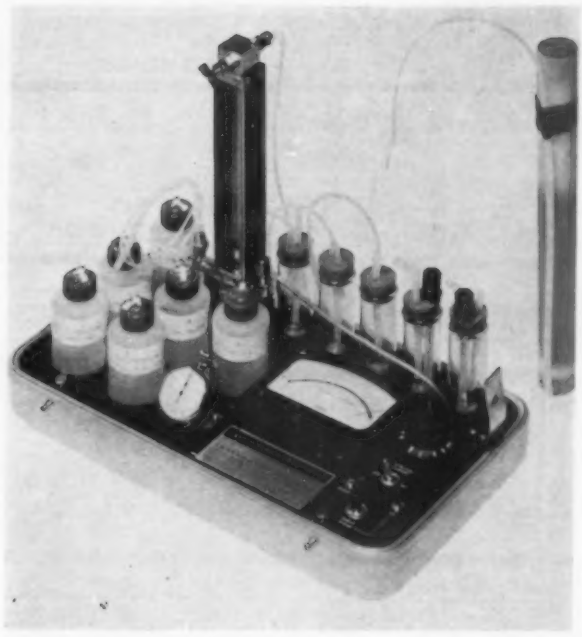


FIG. 2

Sulfur Analysis

ever, feel that the bromine solution is preferable. Therefore, some of the solutions have been modified or substituted in company instruments. The solutions used are as follows:

Bottle #1 0.3 N KBr—1N H_2SO_4 —Titration solution
Bottle #2 1% $CdSO_4$—2% H_3BO_3—Hydrogen sulfide scrubber
Bottle #3 3 N NaOH —Mercaptan scrubber
Bottle #4 0.5% $AgNO_3$ —Sulfide scrubber
Bottle #5 Distilled H_2O.

The flowrator, filters, and cells are all connected by special polyethylene tubing with tapered ends for ease of connection to the cells. Polyethylene has been shown to be free from significant absorption of sulfur compounds.

The Austin apparatus generates by electrolysis measured amounts of bromine, which reacts with the sulfur compounds in the gas. The reagent generating current is supplied by two 4-volt mercury dry cells connected in series and is regulated by the manual current control knob on the panel. Readings are taken from the meter. The meter is a dual purpose 0 to 2 milliammeter with a button control that will increase its range to 10 milliamperes and functions to measure the generating current when in the "check" position, or functions in the sensing circuit as a measure of the excess bromine in the generating cell when in the normal position.

In continuous titrations the current is adjusted until the meter reading remains constant at a point indicating the desired "end point" concentration of bromine. The choice of the desired end point is one of convenience and ease in calculations, and is marked on the milliammeter in red at 0.3 milliamperes for bromine titrations.

It now follows that concentrations of titrated compounds in the gas will be determined by the flow rate of the sample and the generating current used to reach the end point. To further reduce the variables, a sample flow rate of 500 cc per

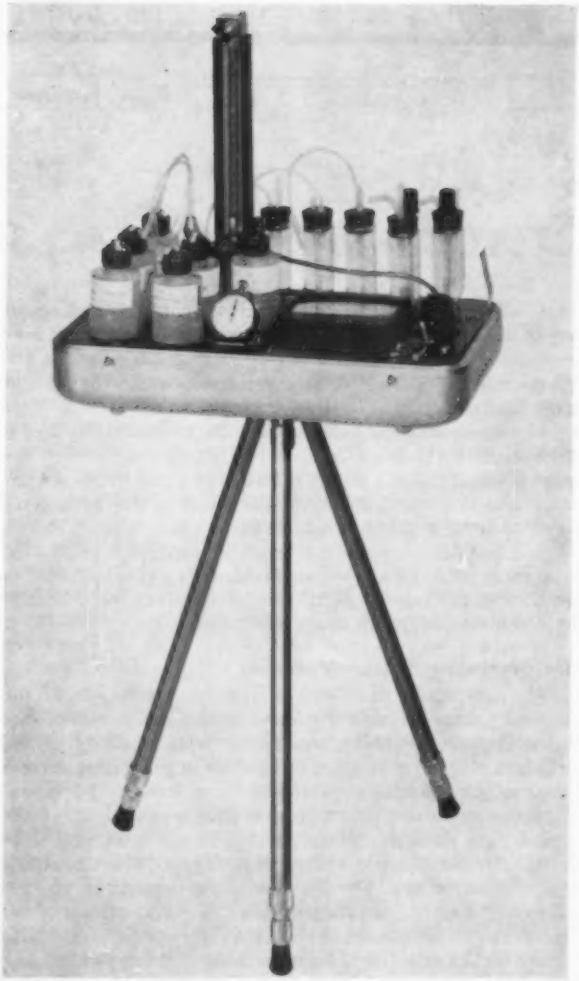


FIG. 3

TRANSWESTERN PIPELINE COMPANY
MEASUREMENT DEPARTMENT
SULPHUR DETERMINATION TEST REPORT

Company or Producer	Universal	Date	1-1-61
Field or Location	National	Contract Number	000
Source or Reservoir	Regional	Field & Res. No.	000
Well or Station Name	State #1	Station Number	000

Analysis of gas for H_2S, RSH, RSR & RSSR using Austin Titrator

Bromine titration results expressed in milliamperes generating current required to maintain a fixed level of free bromine in the generating cell during selective scrubbing processes. Gas flow set at 500 cubic centimeters per minute.

Test Data

A.	Blank (filtered sulphur free gas)	.080 ma.
B.	Total Sulphur (unscrubbed gas)	4.831 ma.
C.	H_2S removed (selective scrubber)	1.339 ma.
D.	H_2S & RSH removed (selective scrubber)	.419 ma.
E.	H_2S, RSH & RSR removed (selective scrubber)	.278 ma.
A¹.	Blank rerun (If A¹ ≠ A, rerun)	.080 ma.

Calculations

Sulphur Derivative		Equation	Grains/100 CF
H_2S	Hydrogen Sulfide	.52 x (B-C)	1.816
RSH	Mercaptans	.44 x (C-D)	.405
RSR	Sulfides	.90 x (D-E)	.127
RSSR	Residual Sulphur	.50 x (E-A)	.099
	Total Sulphur		2.447

Remarks

Analysis By Wm Garratt Witness by Jim Noonan

FORM TW-240

FIG. 4

min is used and may be controlled by a flowrator mounted on the instrument panel. This flowrator should first be flow calibrated for the various gas specific gravities to be encountered, using a bubble tube and a stop watch for calibration purposes.

The generating current required to maintain the predetermined free bromine level in the titration cell, when the gas sample is passing through the cell at a rate of 500 cc per min, is only dependent on the amount of sulfur derivatives present in the stream because bromine is used up in reactions with the sulfur compounds, and an increased generating current is required to produce bromine at a rate sufficient to overcome the rate of reaction and maintain the predetermined level designated as the end point.

Determining Sulfur Volumes

The procedure used to determine the amounts of the various sulfur derivatives present in the gas stream is that of selectively scrubbing out the derivatives ahead of the titration cell and noting the differences in generating current required to maintain the same bromine level.

The starting point for this procedure is obtained by passing the gas through activated charcoal and molecular sieve filter into the titration cell to determine a "blank" reading for sulfur-free gas. The filter is then removed and the gas is passed directly into the titration cell ahead of any of the scrubbers to determine the generating current required to maintain the established bromine level in the presence of all the sulfur compounds in the gas stream. Once this value has been determined, it is a simple procedure to route the incoming gas through the selective filters to remove the hydrogen sulfide, mercaptans, and sulfides in turn, and note the decreased generating current required to reach the end point bromine level.

The differences in generating current between the successive filtering processes is a measure of each particular sulfur compound entrained. These differences in required generating currents may be converted directly to grains per 100 cu ft of gas by using the multiplying factors supplied with the instrument. These factors were determined experimentally by Dr. Austin and are based on the different bromine demand factors for the various sulfur compounds. Transwestern Pipeline Company has incorporated these factors into a Sulfur Determination Test Report for calculation of test results, as shown in Fig 4.

Calibrating the Instrument

In order to prove the accuracy of the instrument, periodic calibration tests are made by Transwestern in the following manner. A .05 cc sample of pure hydrogen sulfide is placed in a previously equilibrated 50 cc syringe. Air is admitted to bring the volume to 50 cc. At this point barometric pressure and temperature readings are made. The syringe is then mounted in a bracket as to allow the needle to probe the tubing extending from the titration cell. A small motor is mounted in such a manner that by placing a driving disc on the shaft it will cause the plunger in the syringe to rotate at a fixed speed, thus allowing the enclosed hydrogen sulfide and air mixture to be dispensed at a constant rate. A vacuum pump is connected downstream of the flowrator. With the use of a bubble tube, a flow rate of 500 cc per min of air is drawn into the titration cell. A blank reading for air is obtained at this time.

It is into this air stream that the calibrating hydrogen sulfide and air mixture is dispensed. When the free bromine level or end point is again reached by manually adjusting the generating current, the resulting increase in generating current value is noted. A stop watch is used to measure the time required to dispense a 5 cc sample of the calibrating mixture from the syringe.

The amount of hydrogen sulfide present in the air stream is then calculated, based on the generating current values shown by the instrument, and compared to the calculated amount of hydrogen sulfide that was actually present in the air stream. These two values based on completely different procedures should not, and do not, vary by more than a few thousandths of a grain per 100 cu ft of gas. ★ ★ ★

ABOUT THE AUTHOR

William A. Garratt is a measurement analyst in charge of Transwestern's Kermit, Texas, laboratory. He is a graduate of Hastings College and the University of Omaha. His studies also include two years at the University of Nebraska, College of Medicine. He was formerly employed by Northern Natural Gas Company as a senior chemist, later as a supervisor in Northern's measurement department. His service with Transwestern dates from June 16, 1960.

First stage turbine wheel is lowered inside frame. Wheel has been returned from machine shop where it has been worked on for balance and cleanliness.

Angle of coupling is checked with instruments by repairmen when assembling turbine after overhaul.

EQUIPMENT MAINTENANCE
. . . one of a series

HOW TO OVERHAUL A GAS TURBINE

ROBERT BURKE, *El Paso Natural Gas Company*

OVERHAULING A GAS TURBINE, as practiced by El Paso Natural Gas Company, is a systematic procedure, planned to keep the turbine in service on the line as long as possible but to prolong its working life by scheduling periodic maintenance.

Although the turbine in industry is still in its adolescent years, its use has been endorsed for all kinds of work where a steady production of horsepower is needed. Thirty-four gas turbines are used by El Paso Natural on its mainline systems.

These turbines use a relatively small amount of fuel in normal operations. Because it has few moving parts, the turbine is easy to maintain. And it can work a long time without frequent overhauling.

But one thing the gas turbine demands is proper care, and the time it takes to do it right is well worth the effort.

El Paso Natural plans its overhauling schedule to include 12 turbine stations, located in West Texas, New Mexico, and Arizona. Between turbine stations on the mainline are compressor stations powered by reciprocal engines. Station personnel do the required annual overhaul on these engines, but a crew of specialists has been assembled and trained to work on the turbines.

A turbine is rated according to the number of hours it can work before it needs maintenance overhaul. These stations operate 24 hours a day, seven days a week. Average time between maintenance overhauls on any one turbine is three years. Of course, the gas turbine could probably stay on the line longer, without trouble, but it is wiser to schedule maintenance in time to make sure the turbine is operating properly. Otherwise it might break down in a crucial peak season.

Scheduling the Overhaul

A record is kept for each turbine in the system and when time comes for the maintenance overhaul, the systems dispatcher is notified so he can suggest a date the turbine can be relieved and not hamper overall pipeline operations. It is best to get maintenance out of the way during the summer months when gas demand is lowest; however, when necessary, it is possible to do the work in any season.

El Paso Natural's turbine stations have three turbines installed. In a typical station, Afton station south of Las Cruces, New Mexico, for instance, the turbines sit on two 12-in. pipelines, one 26-in. pipeline, and one 30-in. pipeline. Piping in the station is arranged so that gas passes through three compressors, arranged in series.

Additional piping is installed to permit the operator to pass gas through any of the three, allowing him to bypass one or more compressors without interrupting main line service. This is the perfect arrangement for providing maintenance or handling emergency breakdowns.

As a rule of thumb, pipeline gas enters the station at a pressure of 600

psi. After passing through three compressors, the gas emerges at 800 psi and rejoins the main line for its next leg of the journey.

Centrifugal compressors are connected to the gas turbines by a driveshaft. One compressor takes 16,500 cu ft of gas a minute, whirls it inside the compression chamber, and pushes it out the discharge side. Working in series, a compressor boosts the pressure of pipeline gas by 60 to 70 psi. Pushed in and out of compressors connected in series of three, the gas gets back up to mainline pressure in a hurry.

Each Overhaul—800 Manhours

It takes about 800 man-hours to complete a thorough gas turbine overhaul, including five days just to dismantle the turbine and get it ready for the cleaning work. Under normal conditions, the entire overhauling operation is completed within two weeks.

By doing 11 or 12 overhauls a year, mostly in summer months, every turbine in the company's system can be overhauled in the three year maintenance period.

Operation of the Turbine

Basically, a gas turbine operates in a simple way. Its primary parts are two turbine wheels and two driveshafts. Each wheel is about 4 ft in diameter. The principle of the gas turbine is that gas fuel is fired in combustion chambers to produce the pressure of expanding gases. As these gases are directed toward the turbine wheels, the wheels revolve, turning the driveshafts and producing horsepower.

In gas turbines used by El Paso Natural, large suction pipes draw air from the outside into the turbine. This air is compressed by the axial flow compressor and returned to the regenerator, built around the exhaust tower, where the compressed air is heated to 700 to 750 F. It takes less fuel to expand air if the air is already hot. All air drawn into the turbine is cleansed by sets of filters before being taken into the turbine compressor unit.

The fuel section of the turbine, meanwhile, takes natural gas from the suction side of the main lines. Fuel is taken in the station at 125-psi pressure. Instruments regulate the flow of fuel, reducing the pressure, until the time it goes into the turbine firing chambers where it must be exactly one and one-half times the pressure of the air with which it is mixed.

As the axial flow compressor operates on the turbine wheel driveshaft, the compression of outside air cannot be controlled. Usually, however, the air arrives inside the turbine at 60-psi pressure, so the final cut of the fuel holds it at 90 psi plus pre-set on pressure-ratio valve. This ratio has been found ideal for pipeline operations.

Firing chambers of the turbine are arranged in a circle outside the turbine, three chambers on each side of the main housing. Gas is fed to the chamber through a nozzle and is burned by continuous combustion. Air flowing in the chamber acts as a cushion around the flame and mixes with the burning gases. As these gases expand and rush through the chamber, the flow is directed to the first stage turbine wheel by metal nozzles. The buckets on the outside rim of the turbine wheel momentarily hold the gases and are themselves rotated. The first stage turbine wheel receives the first push of the expanding gases, revolving faster than the other wheel. The first stage wheel takes about 78% of the horsepower and uses this to run the turbine. This wheel is connected to a driveshaft that runs back through the turbine and operates the axial flow compressor.

The second stage turbine wheel, situated just inches away from the first stage wheel, gets the rest of the energy. Although the two wheels are near each other, there is no connecting link. Expanding gases are directed to the buckets of the second stage wheel by another set of nozzles, strike the wheel buckets with their remaining force, and push onward through the turbine.

After gases have passed through both wheels, the gases are caught in a metal cage, vented to slow down the gases. The exhaust flows down from the cage, under the turbine, and rises through a tower outside the station building. Heat from the exhaust warms incoming air passing downward in the regenerator.

Running at top speed, the second stage turbine wheel turns at 5500 rpm. A driveshaft connects the second stage turbine wheel with the impeller in the compressor. Revolving at the same speed, the impeller does the work of compression.

A compressor is housed in a metal cage, a half-circle in shape. Suction gas comes in one side and is routed to the face of the impeller. Gas is caught in the impeller blades and whirled once around the impeller chamber. Compressed by centrifugal force, pipeline gas is shot out of the compressor at the bottom in the discharge line.

Delicate instruments provide final check in reassembly of turbine shafts. These men are checking thrust bearing clearance.

Each wheel bearing is taken apart for complete inspection. If parts need replacing, repair crew installs them and checks for perfect operating condition.

Stator blades from axial flow compressor are wiped clean and inspected thoroughly before being replaced in the turbine.

Overhauling a turbine takes a lot of tools, of all sizes and different types. Here are shown only a part of the many kinds used.

Steps in an Overhaul

Perhaps the biggest job in a turbine overhaul is taking it apart. First, the compressor has to be taken off the line. Pipeline gas is routed through the two active compressors only and back to the mainlines, bypassing the turbine compressor that will be serviced.

The gas turbine is shut off by closing down its fuel intake. Piping to the turbine is disconnected and removed. This includes pipes for fuel intake, pipes that deliver oil to the driveshaft bearings, and pipes that take cooling water to the gas nozzles. These lines are cleaned and examined to be sure they are free of any obstructions that would delay the flow of gas, oil, or water to the turbine locations where they are needed.

The crew then removes the six combustion chambers outside the turbine housing. These are taken off and set aside for later work. Half the metal cage that covers the fast-revolving turbine wheels comes off. With the turbine wheels exposed, the men unbolt the second stage wheel from the compressor impeller and remove the wheel and its driveshaft. The second half of the housing can then be taken off. This enables the men to get to the diaphragm that covers the inside cavities of the turbine and remove that also. Next, the crew unbolts and removes the first stage turbine wheel from the axial flow compressor.

The axial flow compressor is a cylinder-shaped part with small metal blades protruding from its surface. It revolves at the same speed as the first stage turbine wheel and compresses incoming air before the air is heated in the regenerator.

These three parts — two turbine wheels and axial flow compressor — are taken by truck, regardless of station location, to El Paso Natural's Station No. 3, near El Paso, Texas. Shop employees check the turbine wheels for cracks or flaws in the metal. Buckets on the rim are removed, individually cleaned, and inspected.

The wheel is put on a special instrument that tests it for exact balance. If the metal is worn, the entire wheel is polished and smoothed until the metal displacement is uniform. A slight imperfection in wheel balance can cause serious damage by letting the wheel vibrate. Vibration could twist, or even break, the driveshaft, resulting in costly repairs.

When the wheels and axial flow compressor are cleaned and checked for perfect balance, they are returned to the station. But while these parts are being cleaned, combustion chambers of the turbine are cleaned with wire brushes. Every part of the turbine, every bolt, every strip of metal, is steam cleaned and polished. Every piece is examined for cracks and chips.

Where there is a revolving driveshaft, there must be a bearing. Gas turbines have five. The overhaul crew takes apart each bearing to be sure all parts are uniform and make certain oil seals are intact. When cleaned and inspected, bearings are replaced on the driveshafts after the wheels have been returned.

Acid is forced through the second stage sets of nozzles that direct expanding gases to the wheel. Each wheel has a separate set. The first stage nozzles are fixed. Nozzles for the second stage wheel are variable and the speed and operation of the turbine can be controlled by changing the angle of the moving gases as they strike the wheel. These nozzles are water-cooled, and the water jackets are cleaned to remove mineral deposits that may have collected.

At times, sand and bits of metal are found in parts of the turbine during overhaul. These foreign substances need to be explained. Workmen keep records on these unusual items, find the solution to why they are there, and apply the answers to the next overhaul. Undue wear, worn parts, and any unusual circumstance is noted and kept on file.

Skilled repairmen from another section go over the turbine's instruments. The three main instruments on the turbine are the gas control valve, the pressure-ratio valve, and the fuel regulator. Gas fuel arrives at the turbine at a pressure of 125 psi. The pressure-ratio valve sets the gas fuel at exactly one and one-half times the pressure of the incoming air. The gas control valve, regulated by a signal from the fuel regulator, makes a final pressure adjustment on the fuel before being injected into the firing chambers.

During a complete turbine overhaul, the compressor also is given attention. The front of the compressor is unbolted and the impeller taken out. The inside is cleaned with wire brushes and a cleaning solvent if necessary. The impeller is balanced and replaced. The front piece is closed and bolted tight.

With all parts cleaned, inspected for minute wear and tear, and new parts put in where needed, the turbine is ready to be assembled. Another few days of work to put it back in shape and the overhaul is complete. ★ ★ ★

FIG. 1. Device for open-end blowing of gas from pipeline or for pig to escape at end of pig run.

NEW CLEANING METHOD AVOIDS

DAVID C. PALM

ABOUT THE AUTHOR

David C. Palm, general superintendent of pipelines for Natural Pipeline Company of America, joined the company when it was organized in 1931. He has spent his entire engineering career in the petroleum and natural gas industries in the fields of design, construction, and operation. He has served on numerous industry committees and is presently a member of the Transmission Committee of the American Gas Association.

WHEN PIPE SECTIONS with bright and shining interior coatings are strung on a dusty or muddy right-of-way and welded together to form a pipeline, their bright interior luster may be temporarily dulled, because during the construction process foreign matter finds its way to the interior pipe surface.

Open-end pigging using wire brushes on the pig has been the accepted practice to loosen foreign matter from pipe walls and sweep and blow it out of the line. However, the growing use of internally located line pipe calls for modifications in cleaning the line following construction due to the possibility of damaging the coating.

The Gulf Coast Division of Natural Gas Pipeline Company of America recently completed the laying of 371 miles of 30-in. pipeline coated on the interior wtih a 1.5 mils dry film thickness of epoxy-resin. Much of this line was laid under extremely dusty conditions. Therefore, it was recognized that thorough cleaning was necessary before the line was placed in operation.

The Procedure

Main line valves are spaced at approximately 15-mile intervals, and each section of the line between valves was a unit in the cleaning program. On the upstream side of a segment, a cut was made and a short section of pipe temporarily placed in the line by means of Dresser couplings. This permitted repeated insertions of the pig in the pipeline. At the other end of the 15-mile segment, a blow unit was coupled into the line. This device consisted of a curved section of pipe to permit the blow gas or pig to escape, and a piece of pipe welded on the tangent at the beginning point of the curvature to form a leg. The customary pig-catching facility, consisting of a section of slotted pipe with a capped end, was used for trapping the pig at the end of its passage (Fig. 1).

Our plan for line cleaning was a combination of removing foreign matter by blowing to sweep out excess loose material, then passing a pig one or more times to dislodge remaining foreign matter, and subsequently blowing again to assure a clean line. This procedure was set up to avoid possible damage to the interior coating.

In practice this meant giving the line a purge and a light blow before insertion of the pig, and without the cap on the pig catcher at the outlet of the blow unit. This light blow with a gage pressure of about 12 to 15 psi on the

FIG. 2. Gas stream carrying foreign matter escaping through slotted openings in pig catcher prior to arrival of pigs.

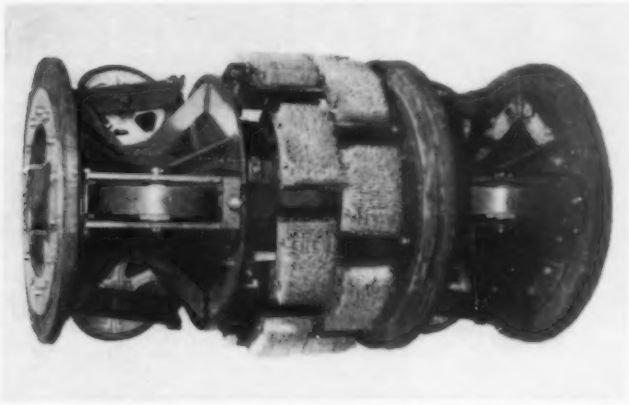


FIG. 3. Wheel suspended pig equipped with nylon brushes. (Photo by courtesy Pipeline Cleaners Company, Fort Madison, Iowa.)

DAMAGE TO INTERNAL COATING

upstream end of the 15-mile section brought out loose material such as sand, dust, refuse from welding, etc.

It was important to remove as much of this as possible prior to passage of the pig, otherwise an accumulation of the debris ahead of the pig or under the brushes or rubber cups would scour the coated pipe surface. Furthermore, it was important that the velocity of the gas stream in the pipeline during the blow be sufficient to carry out any foreign matter, but not so high as to cause a sandblast effect on the coating. This blow was continued as long as an appreciable quantity of foreign matter was being brought out by the gas stream.

The pig was then inserted at the upstream end of the section with the pig catcher in place at the outlet of the blow unit. The pig run resulted in additional foreign matter being loosened and suspended in the gas stream, escaping ahead of the pig and eventually being blown out of the slotted openings in the pig catcher (Fig. 2).

With the pig run completed, another blow followed, with the upstream pressure stepped up to the 20-25 psi range. If the line did not clear in a matter of 15 minutes, the pig run was repeated and followed by another blow.

"Pigs" Modified

Most of our line cleaning utilized the conventional spring loaded brush pigs equipped with wire brushes and tight fitting rubber cups, which have been successful in cleaning non-coated line interiors. However, a modification was made in that we used fine wire brushes, whereas a stiffer brush is customary on uncoated lines in order to remove excessive rust.

We experimented with a pig developed by Pipeline Cleaners Company of Fort Madison, Iowa, using some ideas suggested by our operating men (Fig. 3). In essence, this pig had the following features:

1. It traveled on wheels with the weight of the pig suspended on springs, which gave an even brush pressure around the pipe circle. By eliminating the downward gravity pressure on the moving pig, more uniform brushing was possible.

2. Instead of using tight-fitting cups, there was a small annular space at the pipe circle around each propelling rubber disk. The brushes were so located with respect to these disks that a jet of gas, escaping around the pig, impinged on the area being brushed. This avoided clogging of brushes by debris and also lessened the possibility of foreign matter being lodged under brushes and causing damage to the coating.

3. Brushes of either nylon or soft wire (a grounding wire if nylon) were spring loaded so as to exert uniform pressure.

4. Due to the wheel suspension and the smooth coated pipe interior, the pig moved with a pressure of only 6-8 psi behind it.

In that changes were made during the job as experience was gained, this pig was not used enough to pass beyond the experimental stage, but we felt that it had desirable features and looked promising.

The indications are that the procedure we followed resulted in a clean line using either the conventional pig with fine wire brushes or the experimental wheel-suspended pig with nylon or wire brushes.

At this writing, the new lines have been in service for various periods of time up to 60 days. The system is not equipped with scrubbers at the compressor stations. Therefore, it is significant that there has been no indication of pipeline foreign matter accumulating in compressor cylinders or of abnormal wear of compressor rings or rods. ★ ★ ★

ENGINE FOUNDATIONS

—Design, Theory, and Construction. Part 1

D. A. NESTERENKO, *Principal Structural Engineer, Stanley Engineering Company*

DESIGN of equipment foundations generally is a field much neglected both by mechanical and structural engineers.

Often little attention is given to the shape of the equipment foundation until portions of the building and other facilities are designed.

In some cases, this may mean that the equipment foundation must fit into the opening left in the floor and that the approximate height of the foundation has already been established — these conditions having been set to accommodate general arrangement of the plant and building rather than through proper design of the foundation itself.

Frequently, because of overall economy, the distance between major pieces of equipment is insufficient to allow for a foundation with a relatively wide base, in cases where such a base would be desirable.

Technical literature concerning equipment foundations is limited. Because of the complicated nature of the problem, no exact computation of vibrations appears to be possible. However, if all information available through various publications can be used, supported by practical experience of personnel occupied with design, the result will be beneficial both to the industry and to the owner of the equipment in question.

A good foundation design means that the life of the equipment will be prolonged, maintenance costs will be reduced, and more satisfactory operation will result.

Foundation Types

In general, equipment foundations may be divided into two basic types.

Type 1 — Block or box foundation. The block foundation is used for many types of equipment or machinery. For example, hammers, diesel engines, air compressors, blowers and fans, coal crushers, etc., normally are supported by block foundations. These foundations usually are constructed as solid masses of reinforced concrete. Sometimes it is necessary to provide cavities or openings inside the foundation block, or it may be necessary to extend the base slab beyond the main concrete foundation block in certain cases.

Type 2 — Rigid frame foundation. Rigid frame foundations also are reinforced concrete structures. Sometimes structural steel members can be used for portable units or for other special purposes.

Framed structures are necessary in order to provide a space under the main equipment. For example, such a space is needed for the condenser and for the piping in the case of turbo-generators.

It will be our intention in this article to present general ideas and approaches taken in the design of foundations for reciprocating engines, based upon the experience and the theoretical approach available to the firm. (In general, Type 1 foundations, with the exception of hammer foundations.)

Design Problems

Generally, three steps are necessary in the design of engine foundations:

1. Procuring general information.
2. Dynamic investigation.
3. Structural design.

General Information

Soil investigations. Procuring general information includes soil investigation through the use of soil borings. It is necessary to determine whether the soil is capable of supporting the engine foundation without excessive settlement. Usually this investigation is a part of the entire soil investigation for the plant.

Standard penetration and unconfined compression tests may be used. The type of soil present (sand, gravel, silt, clay, etc.) determines the particular procedure that should be selected.

If the soil is incapable of supporting the engine foundation, the possibility of using piling or piers should be considered. Also, the sensitivity of sands to the induced vibrations of machinery should not be overlooked. In some cases, compaction of pure sands by vibrating equipment may be obtained, for example, through the use of vibroflotation.

The results of the soil investigation performed by a soils testing laboratory should be presented to the design engineer. In addition, our company inspects the soil samples obtained from the borings to obtain a better understanding of the nature of the soil located beneath the foundation.

The exact depth of the boring must be determined for each particular job; however, in general, depths of the borings vary between 50 and 100 ft.

Basic engine data. It is essential that adequate engine data be obtained from the manufacturer. Our company has what we call a Mechanical Standard Form, which indicates basic information we require for our design.

Dynamic Investigation

It is impossible to design all kinds of machinery having all parts perfectly balanced. Therefore, the engine foundation as an elastic body is subjected to dynamic forces that induce vibrations-unbalanced forces and couples, primary and/or secondary. If the natural frequencies of the foundation are close to the frequency of the exciting force, excessive vibrations due to resonance will occur. The design problem is to select such a foundation shape that this resonance will be prevented. For example, the foundation for an engine operating at 225 rpm with only primary unbalanced forces or couples should have natural frequencies lower or higher than 225 per min to avoid resonance. If the same unit also has unbalanced secondary forces (or couples) the critical natural frequencies for the foundation will be 225 per min and 450 per min (double rpm). The safety factor between engine speed and natural frequencies should be 25 to 50 percent if possible. The larger the safety factor, the better.

The designer first has to assume an approximate foundation shape. This step is a very important one. An experienced man will save a great deal of work by using the approximate correct dimensions. The vertical axis through the center of gravity of the combined unit weight plus the foundation weight (static load) should coincide with the center of gravity of the base slab bearing area. This means that the static pressure should be uniform over the entire bearing area. Many difficulties may arise if this criteria is neglected. In addition, any dynamic investigation might be useless.

Next, it is necessary to determine the location of the horizontal plane through the center of gravity. It is obvious that the center of gravity of the engine and foundation is located on the above mentioned vertical axis somewhere between the bearing area and the crankshaft.

The following nomenclature will be used in the further discussion:

X-X, horizontal longitudinal axis through the center of gravity.

Y-Y, horizontal transverse axis through the center of gravity.

Z-Z, vertical axis through the center of gravity.

XZ, vertical plane through the center of gravity and axis X-X.

YZ, vertical plane through the center of gravity and axis Y-Y.

XY, horizontal plane through the center of gravity.

If the disturbing unbalanced force is vertical acting exactly through the center of gravity, only vertical vibrations will result. Such a case is quite uncommon, however. Any vertical eccentrically applied unbalanced force may be represented as a vertical force acting through the center of gravity plus a moment acting in plane XZ, plane YZ, or both.

Vibrations. A more diffcult problem exists if a horizontal unbalanced force is acting, because it will always be applied above the bearing area. The engine foundation will be subjected not only to horizontal movement but also to "rocking and rolling" of the XZ and YZ planes, respectively. The engine foundation will be subjected to horizontal vibrations about the vertical Z-Z axis, if the horizontal force is acting outside the XZ and YZ planes. Usually, a maximum of six different movements (vibrations) have to be considered:

(1) Vertical.

(2) Twisting about the vertical Z-Z axis.

(3-4) "Rocking" (sometimes called harmonic vibrations in XZ plane)

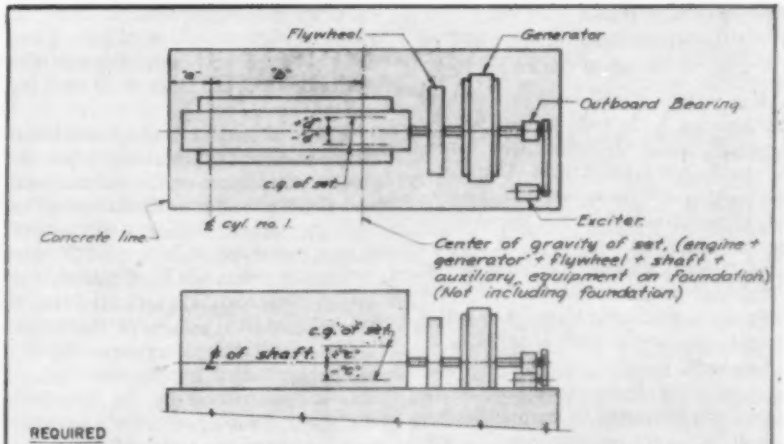
3. Of upper vibration center.
4. Of lower vibration center.

(5-6) "Rolling" or harmonic vibrations in YZ plane.

5. Of upper vibration center.
6. Of lower vibration center.

Because pure horizontal movement of the system is hardly possible, the dynamic theory of equipment foundations assumes that vibrations in the XZ and YZ planes will occur at two centers located on the vertical Z-Z axis of the system. We call these points the upper and lower centers. Proof of the theory is based on differential equations of forced vibrations.

In general, only those vibrations that will correspond to the exciting unbalanced forces have to be checked. The basic engine data supplied by the


Flywheel
Generator
Outboard Bearing
c.g. of set
℄ cyl. no. 1
Exciter
Concrete line
Center of gravity of set, (engine + generator + flywheel + shaft + auxiliary equipment on foundation) (Not including foundation)
c.g. of set
℄ of shaft

REQUIRED

Engine serial number		
Rotative speed		R.P.M.
Bore		inches.
Stroke		inches.
No. of cylinders		
Length of connecting rod		inches.
Crank radius		inches.
Weight of reciprocating parts		pounds.
Unbalanced forces and couples, [location, magnitude, and direction (Primary and Secondary)]		
Distance from concrete line to ℄ cylinder no. 1	'a'	inches.
Distance from ℄ cylinder no. 1 to center of gravity of set	'b'	inches.
Distance from ℄ shaft to center of gravity of set	'c'	inches.
Distance from ℄ shaft to center of gravity of set	'd'	inches.
Weight of generator stator		pounds.
Weight of generator rotor		pounds.
Weight of exciter		pounds.
Weight of outboard bearing		pounds.
Weight of generator shaft		pounds.
Weight of flywheel		pounds.
Weight of auxiliary equipment on foundation		pounds.
Starting torque		ft. pounds.
Stopping torque. (Following loss of fuel without load on generator)		ft. pounds.
Stopping torque. (Following loss of fuel with full load on generator)		ft. pounds.
Weight of engine. (Complete.)		pounds.
Total weight of set		pounds.

REVISIONS					MECHANICAL STANDARD
NO.	DATE	BY	CHK'D	APP'D	EQUIPMENT SUPPORTS
1	9-15-58				DIESEL ENGINE-GENERATOR FOUNDATION DATA
2	10-31-57				
3	12-19-58				
4	6-4-59				
5	9-9-59				STANLEY ENGINEERING COMPANY

MUSCATINE, IOWA CHICAGO, ILLINOIS

DRWN. W.F.B. | CKD. W.F.B. | ENG. W.F.B. | APP'D. | DATE 6-12-58 | SCALE None | NO. M-1101

5.- Unbalanced Couples
4.- Miscellaneous additions.
3.- Added stopping torque notations.
2.- Traced ℄ misc. changes.
1.- Changed title & drawing number.

Mechanical Standard Form used by the writer's company, Stanley Engineering Company.

manufacturer is vital to the foundation design.

Some discussion in the past was centered around vertical vibrations only and entire foundation performance was often evaluated considering vertical vibrations only. We feel that this is not the complete story. We know of existing installations where the foundation was stable in the vertical direction but had large movements, easily noticeable, about the vertical Z-Z axis. For a typical large diesel engine foundation these theoretical computations usually will indicate the following gradation of natural frequencies:

1. *Lowest*-rolling on YZ plane of lower vibration center.
2. Rocking on XZ plane of lower vibration center.
3. Twisting about the vertical Z-Z axis.
4. Vertical.
5. Rolling on YZ plane of upper vibration center.
6. *Highest*-rocking on XZ plane of upper vibration center.

For many diesel engines, natural frequencies 1, 3, and 5 may be disregarded, since no unbalanced forces or couples are present there. Therefore, the rocking vibrations could be the lowest. Variations between vibrations could be quite large.

It appears possible that the lowest vibrations could be substantially less than the vertical vibrations. The ratios $\frac{\text{height}}{\text{width}}$ and $\frac{\text{height}}{\text{length}}$ have a direct influence on all vibrations except the vertical ones. If it is desired to keep vibrations higher, to avoid resonance with a low speed machine, the ratios preferably should be small. The problem of vertical vibrations will be explained later together with some problems of soil mechanics.

To compute all vibrations in the foundation block, two major steps are required. First, a sketch of the foundation and the engine must be drawn. The engine has to be simplified to five or six major pieces, with proper distribution of the weights. Smaller weights may be redistributed among the major pieces.

Computing inertia moments. A sketch will facilitate the second step of computing the inertia moments of the weights to all three major planes XZ, YZ, and XY, the weight inertia moments about axes X-X, Y-Y, and Z-Z, and proper radii of gyration. Also, the inertia moments of the bearing area need to be determined. These steps are needed for further computations to determine the stiffness of the system in various directions.

Because of the simplified engine sketch, the nature of this computation is somewhat approximate. However, because a foundation is heavier than the engine and because the location of the major engine weight is known, the discrepancy usually is small and the direct influence on the computation is not objectionable. If the foundation is supported on piling the same procedure applies except that the inertia moment of the piling instead of the area has to be considered.

Evaluation of the dynamic properties of the soil supporting engine foundations is a major problem deserving a rather extensive explanation.

In the early 1930's a German organization, "Dagebo," began making dynamic investigations of different types of soils to determine values designated "C" and "S" or so-called "dynamic subgrade coefficients" in the vertical and horizontal (at bearing area) directions respectively. The coefficient "C" indicates the static pressure (in kg/cm²) that is required to cause an elastic vertical deflection of soil=1 cm. They used specially built vibrators with maximum bearing areas of 10 sq ft for this purpose.

It was immediately determined that the coefficient "C" increases when the static unit pressure on the soil increases and that for stiffer soils the values of "C" are larger. During these experiments, however, values of "C" and "S" varied somewhat for the same type of soil. This variation indicated clearly the approximate nature of the results because of additional unknown factors. In general, this approximate nature was so understood by the European designers; however, even very approximate results can sometimes be useful.

It is an established fact that using these coefficients, many foundation problems in Europe and in U. S. have been solved successfully. Assume, for instance, the previously mentioned diesel engine with a speed of 225 rpm, primary and secondary unbalanced couples are acting as indicated by the manufacturer. Therefore, the critical natural frequencies for the foundation are 225 per min and 450 per min. Exploration of the soil indicates a stiff clay. For clay soil and the proper unit pressure, the "Dagebo" table indicates several coefficients of various magnitudes. Assume **A** is the smallest coefficient and **K** is the largest coefficient. The actual coefficient for the soil in question would probably be somewhere between these two values. In this particular case, however, the foundation has to accommodate a low speed engine. Therefore, the only important coefficients are those with low values that will produce low natural foundation frequencies.

If the low or lowest value of the coefficient is selected and all computed vibrations are safely above 450 per min, satisfactory performance usually will result. Selection of the coefficients has to be on the safe side to cover possible variations in the approximate procedure.

A more difficult situation arises when it is necessary to have some of the natural frequencies above and some below the critical speeds. Even in such a case, much can be done to minimize the problem. It is quite true that the design engineers using "Dagebo" coefficients were interested in the extreme values (ranges) only, knowing the approximate character of the investigation. Their only concern was to keep the foundation out of resonance as much as possible, and not to compute the exact number of vibrations. The error is also minimized since values of soil mechanics are always under a square root sign in dynamic investigation. In especially difficult situations, something must be sacrificed. Consequently, a foundation shape will be selected in such a manner that the frequency of the plane with the smallest unbalanced couples is closer to resonance than are the other frequencies. It is always necessary to check later in the field to assure that the original design assumptions were correct and to avoid the same errors on future jobs.

(To be continued)

D. A. Nesterenko *was born in Kiev, Ukraina, in 1909, and was graduated in 1935 from Technical University in Warsaw, Poland, with a degree of civil engineer, equivalent to MS in civil engineering. After graduation he employed his training in industry for a period of time, and shortly before World War II was named chief instructor at Technical University to supervise structural graduate work.*

Immediately after the end of the war he was employed in West Germany by UNRRA and American Army headquarters. In 1948 he came to the U. S. and has been an American citizen since 1954.

From 1948 to the present he has been employed by Stanley Engineering Company, Muscatine, Iowa.

Instrumentation, Controls, and Automation

Part 6: Telemetering

MAX T. NIGH

Supervisory Indication Code Message

IN PAST DISCUSSIONS, we have developed digital telemetering language or code patterns through bits, characters, words, and messages. Let us now look at some messages and see what information they contain. Basically any message is considered complete when it contains three parts:

1. Identification, or address of the data
2. The data itself, and
3. Additional data concerned with validity or verification of the data.

Fig. 20 shows an oscillographic record of the pulse pattern of a message containing 24 bits. Note this message is a pulse code pattern using only one state to convey information, in this case the "mark" state. Also, a long pulse indicates a "yes" and a short pulse a "no." The oscillographic record does not show the pulses as perfect square boxes, but rather shows the real character of pulse patterns with the imperfections of relay response in both the receiver and transmitter. These imperfections in pattern present no problem to a digital system with adequate "margin" in the system design.

Address Portion of Message

Bits C and G identify the particular data quantity being transmitted. Usually the first 8 bits are used for the address, thus permitting many data quantities to be identified.

Data Portion of Message

Bits J through Z are used for data. In the top message pattern bits V, W, Y and Z are shown as long pulses or in the "yes" condition, the rest being short pulses or "no."

The only bit which changed state in the bottom message is the V bit. It is shown as a "yes" in the top message, and as a "no" in the bottom message.

The V bit is assigned to a particular pump, identified as C and G both "yes" in the address portion of the message, and is represented as being "on" or running when the V bit is long and "off" or not running when the V bit is short.

This type of information is often called a supervisory indication because the information usually handled by supervisory control systems over the past 20 years has been the status of machinery.

Today the information handled by supervisory control systems is much more varied. It is now common for them to handle digital data as well as the status of machinery. The term information "handling" would be considered a better description of the work done by digital systems today.

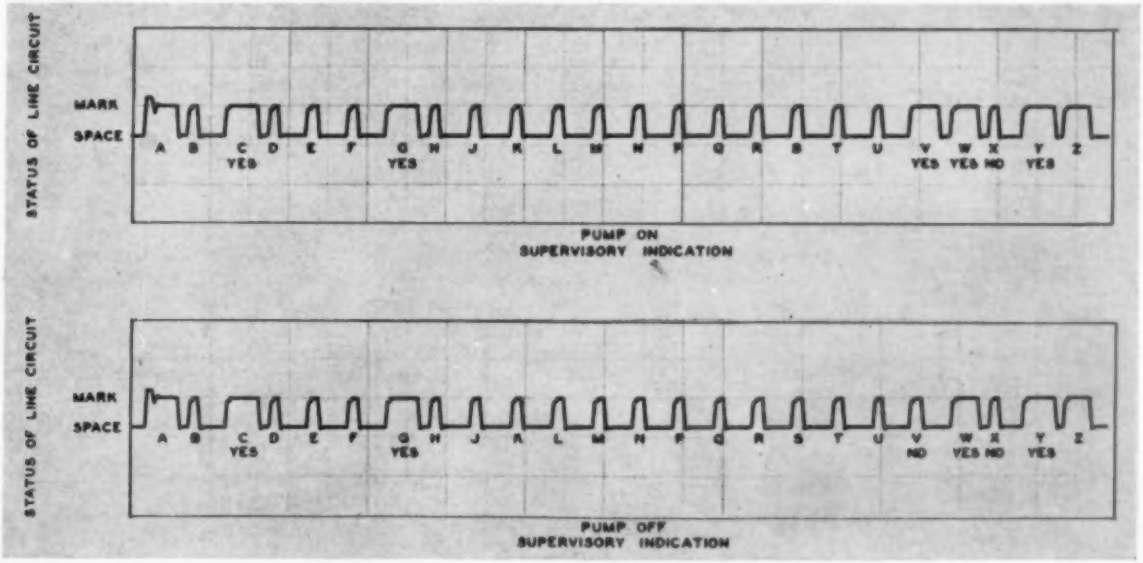

STATUS OF LINE CIRCUIT
MARK
SPACE
A B C D E F G H J K L M N P Q R S T U V W X Y Z
YES YES YES YES NO YES
PUMP ON
SUPERVISORY INDICATION
STATUS OF LINE CIRCUIT
MARK
SPACE
A B C D E F G H J K L M N P Q R S T U V W X Y Z
YES YES NO YES NO YES
PUMP OFF
SUPERVISORY INDICATION

FIG. 20. Example 1 of supervisory indication code pattern.

Validity or Security Portion of Message

The message shown in Fig. 20 is used in a common tank level transmitting system and is generated by a synchronous motor rotating a contacting bar over a printed circuit. The message length is fixed at 24 bits for the particular unit shown. The receiver must receive 24 bits in any one message to be acceptable. Thus a validity check can be made on the message length. It is usually referred to as totalizing. The total number of bits in the message has to be correct before validation can take place.

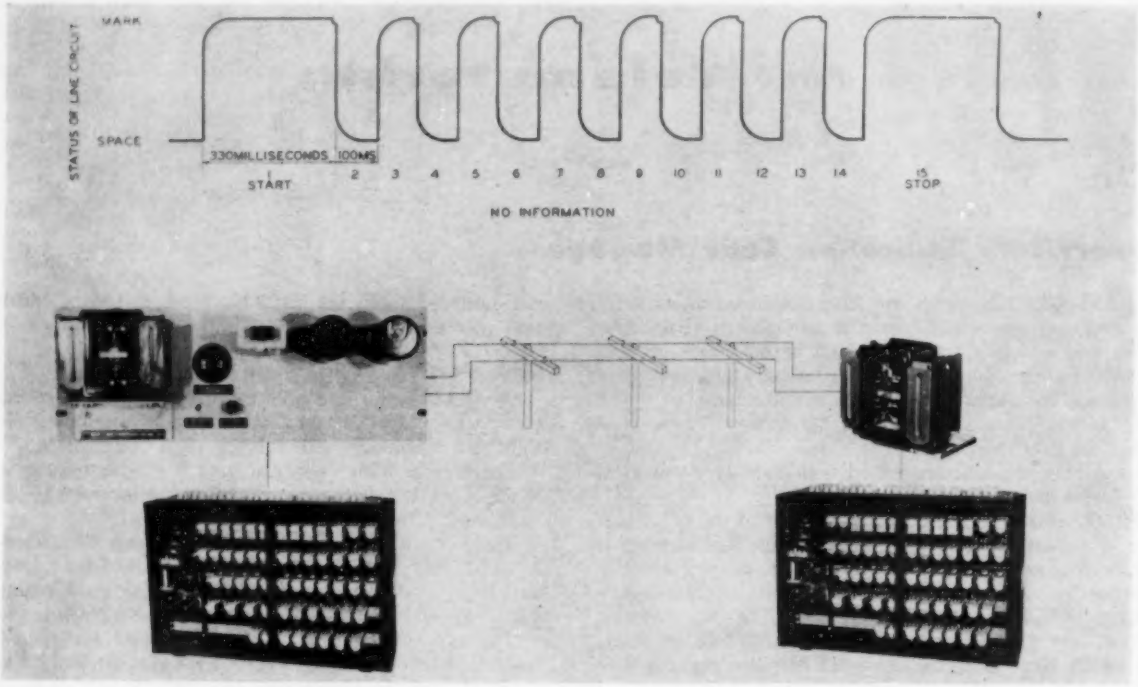


FIG. 21. Example 2 of supervisory indication code pattern.

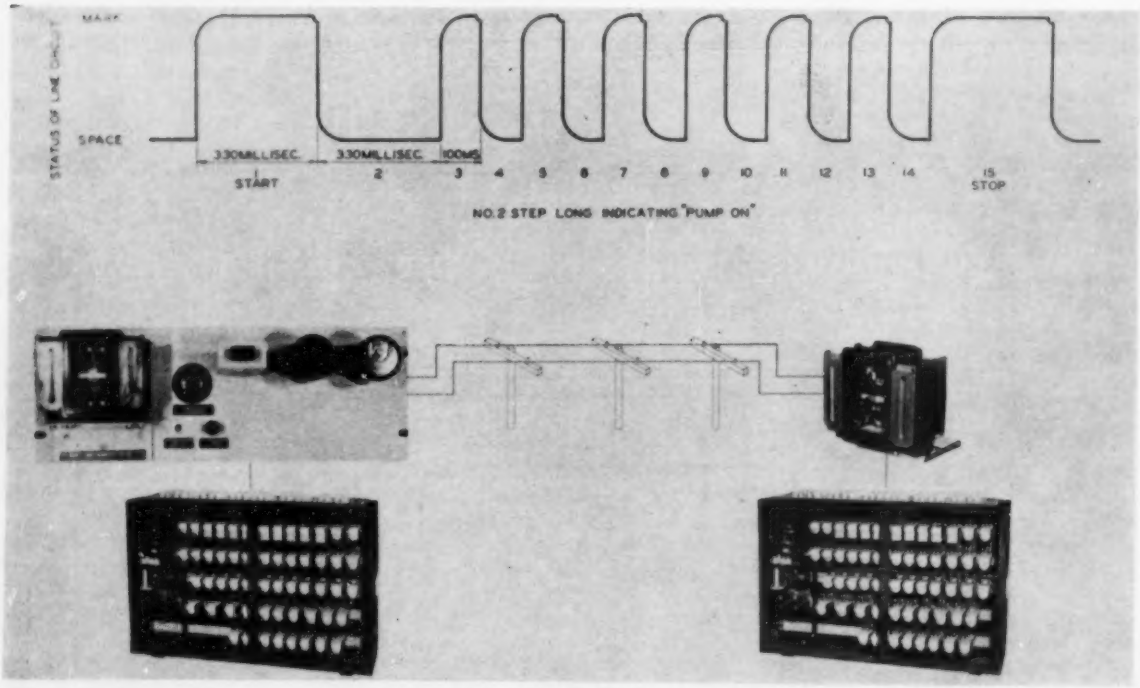


FIG. 22. Pump "on"... supervisory indication code pattern.

Pulse Code Message Using Both Mark and Space for Information

Fig. 21 shows a message pattern that uses pulse length to establish the "yes" and "no" information. Both mark and space are used to characterize each bit. The lengths of pulses 2 through 14 are shown to be short. For this discussion let us assume that a short pulse or "no" refers to no information. The reason for this will be apparent when we discuss the validity contained in this message. The start and stop pulses, numbers 1 and 15, are shown long and are used for synchronization of the message and not for information.

This message contains the three elements typical of any digital telemetering message — address, data, and validity.

Generation of Message

Shown in the lower portion of Fig. 21 is an example of the equipment required to generate, transmit, and accept this message pattern. A relay configuration is shown. It could just as well be a solid-state system or other electromechanical system. The actual equipment shown is not as significant as the function the machinery fulfills in the system. We show a transmitter in the lower left-hand corner. This operates the line relay, shown in the panel above the transmitter on the left end. This line relay "keys" or closes and opens the telephone line circuit to create a pattern in time like that shown in the upper portion of Fig. 21.

Reception of Message

On the right side of Fig. 21 is shown the receiving relay being "keyed" by the pulse pattern present in the line circuit. Immediately below this is shown the receiver. The receiver keeps in step with the pulse pattern generated and checks the message for validity, senses the information contained, and stores the information in relays either energized or de-energized. These relays operate either lights or pushbuttons to display and carry out the intent of the message.

Supervisory Indication Information

Fig. 22 shows Step 2 long and is intended to indicate that a pumping unit is "on," or running.

Fig. 23 shows Step 2 to be short and Step 3 to be long. This is intended to convey that the pumping unit is not running, or is "off."

Validity Checking by Using Positive Information

In other words, the sending of Step 2 as a short was not interpreted as indicating the pumping unit was not running, but rather it took a different step, being long, to indicate it was not running. This technique is not efficient in terms of use of bits, but it certainly provides increased validity of information.

The purpose of this discussion is to emphasize the problem that the lack of a long pulse is difficult to interpret. Often the basis for establishing a long pulse is an energized relay or circuit. Therefore, a failure of the relay or circuit could create a short pulse just as the primary measurement could indicate its status to the supervisory control system in terms of a short pulse. Therefore, it is not possible to be sure of the status of machinery if a failure of the sensing circuits would provide the same intelligence.

Fail Safe Approach

To make the system "fail safe" and provide a check against a sensing or receiving circuit failure, separate bits are used to indicate machinery status — one bit long for running and a separate one long for not running.

I have chosen to call this positive information. This is based upon the philosophy that the absence of information associated with energized circuits is considered to be no information.

The use of this technique is available to the design or application engineer when he specifies a system. When management decision dictates that the engineer design as secure a system as possible, within sensible economics, this technique is highly recommended. ★ ★ ★

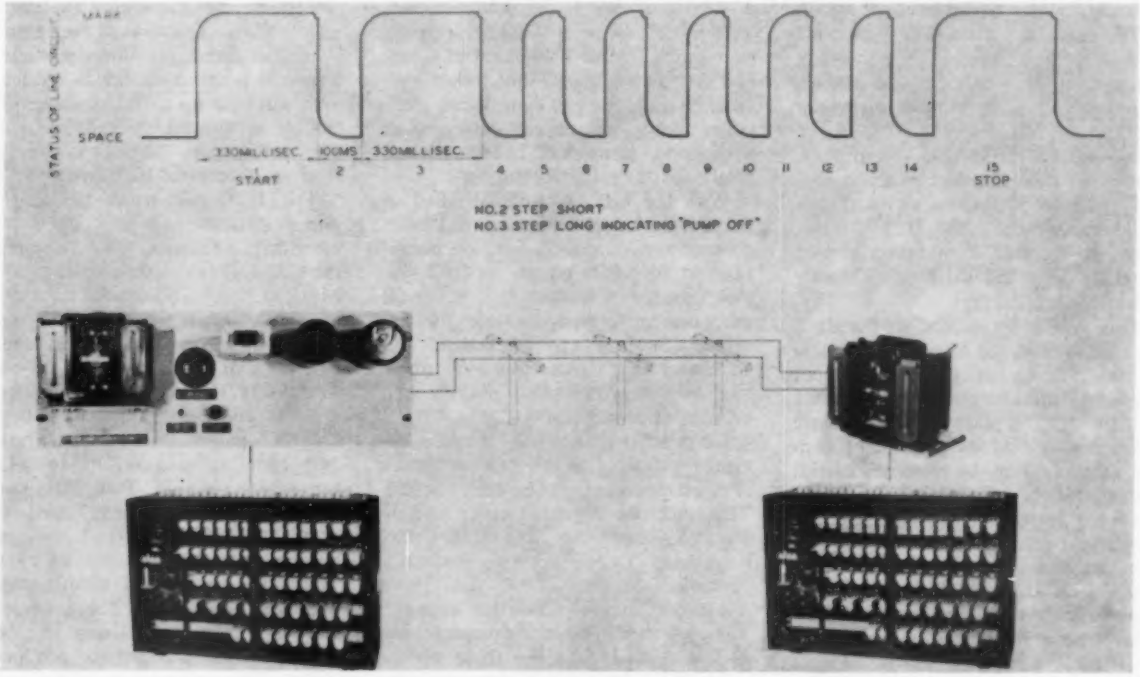
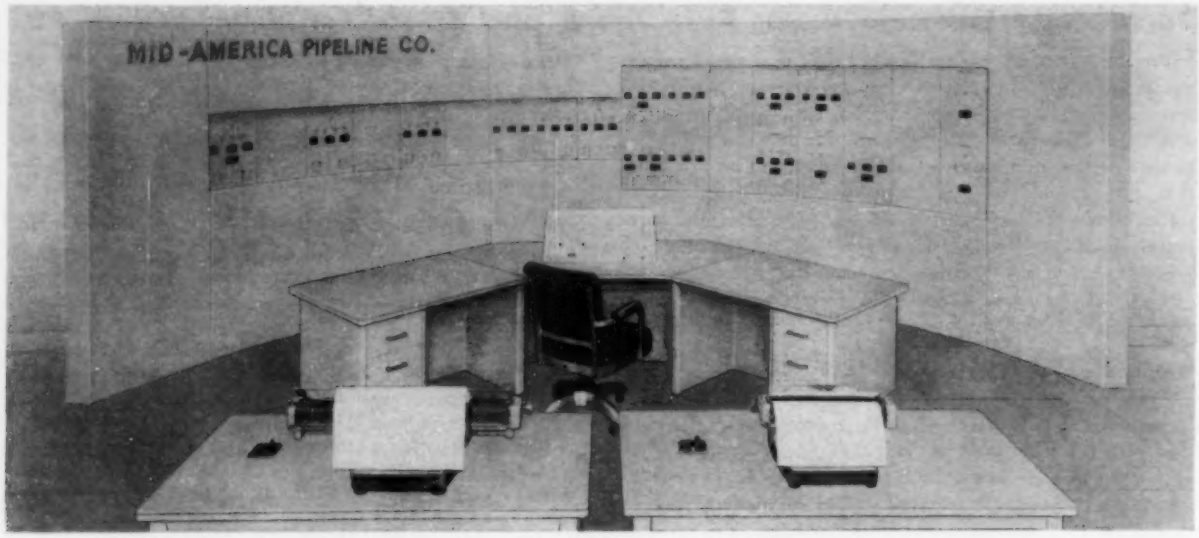


FIG. 23. Pump "off" . . . supervisory indication code pattern.



Curved panel in front of control console contains schematic representation of Mid-America Pipeline system.

MID-AMERICA CHECKS OUT CONTROL EQUIPMENT

AN UNUSUAL OPERATION of a unique pipeline system was demonstrated recently at the Pittsburgh plant of Union Switch and Signal—Division of Westinghouse Air Brake Company.

On that day, from a seat before a Centralized Transport Control console designed and built by Union Switch and Signal, R. E. Thomas, president of Mid-America Pipeline Company, pushed a button that transmitted a control code from Pittsburgh to Tulsa, Oklahoma, more than 1200 miles away, to operate a pumping station situated along the existing 1700-mile pipeline.

This feat is significant in that it is the first time in the history of pipeline operation that such control equipment has been "checked out" for immediate operation at the place of origin before being installed at its permanent control location. For the purposes of this demonstration, communications facilities were brought from Tulsa to Pittsburgh to permit operation of the system. At the completion of the program, the CTC console and its related equipment were shipped to the Tulsa control point for final installation.

Mid-America Pipeline system, designed and constructed by Williams Brothers Company, is considered unique in that it is the only independent common carrier pipeline designed exclusively for the movement of liquefied petroleum gas. While other systems have added LPG products—propane, butane, natural gas—after initial operations, none has been designed solely for their transportation[1].

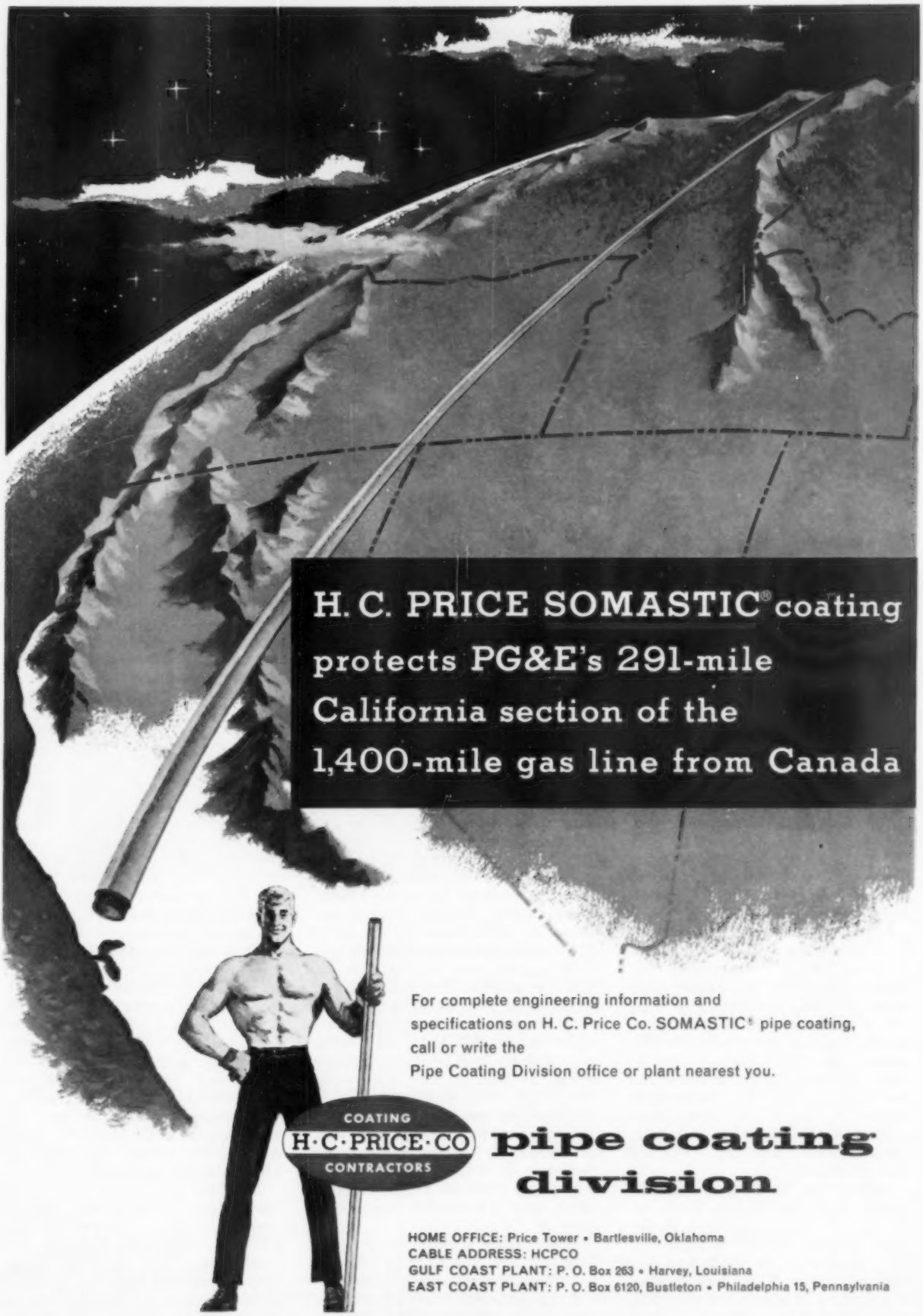
With the CTC console installed in the Tulsa control office, one man can control and monitor operating conditions at all points on the pipeline system, adjust rate of flow and pressures, and operate the pump stations and terminals. Stations can be started and shutdown in their entirety, or single engines within individual stations can be started or stopped.

Completely integrated control is designed into the CTC equipment, which is operated from the control console. This includes digital remote control and telemetering, a new positive displacement meter control, sequence control, instrumentation, data handling, computation, data for accounting, and coordinated communications.

The curved panel in front of the control console (see photo) comprises a schematic representation of the Mid-America Pipeline system. The panel contains data readout instruments, which at all times show positive displacement meter readings, the suction and discharge pressures at each station. When an alarm condition prevails at a specific point in the line, a red alarm light will light up to indicate where the trouble is located. An audible alarm also will sound. The dispatcher can then act to correct the situation.

The 1700-mile trunk line has 15 pump stations and is connected to more than 30 natural gasoline plants in the west Texas, southeastern New Mexico, and Oklahoma Panhandle area. The main trunk line originates near Hobbs, New Mexico, and extends east to Seminole, Texas, and on north to Conway, Kansas. Here it divides into a Y-shaped pipeline. The West Leg of the "Y" passes Lincoln and Omaha, Nebraska, and Sioux City, Iowa, and terminates near St. Paul, Minnesota. The East Leg passes near Kansas City and Moberly, Missouri, turns northward to pass Ottumwa, Iowa City, and Dubuque, Iowa, and terminates in Janesville, Wisconsin. There are seven delivery terminals along the way. Eighty thousand barrels of products a day will be delivered to points on the West and East Legs. ★ ★ ★

1"Mid-America: Only System Designed Solely for LPG," Frank H. Love, *Pipeline Engineer*, November, 1960.



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PIPELINE RESEARCH REACHES MILESTONE

Eight-years' work on pipe performance by AGA-Battelle Institute is paying off in improved design procedures

FRANK H. LOVE, EDITOR

A MILESTONE has been reached in the American Gas Association's pipeline research program. After eight years of work aimed at improved transmission of natural gas, it now feels that certain recommendations can be made with regard to the manufacture of pipe and how it should be tested and inspected.

Results of the eight-year program were discussed comprehensively for the first time at a seminar held recently in Dallas, Texas. Research has been conducted principally at the Battelle Memorial Institute, Columbus, Ohio, under A.G.A. sponsorship. Objective: To learn more about performance characteristics of line pipe and to develop safe and practical pipeline design procedures.

Presiding at the seminar were: Baxter D. Goodrich, senior vice president of Texas Eastern Transmission Corporation; Raymond H. Crowe, chief engineer, Transcontinental Gas Pipe Line Corporation; J. L. Thompson, general superintendent, Michigan-Wisconsin Pipe Line Company; Joe T. Innis, vice president, Northern Natural Gas Company; R. S. Ryan, supervisory engineer, Columbia Gas System Service Corporation; and S. J. Cunningham, senior research engineer, American Gas Association.

Participating in the program from Battelle Memorial Institute were: Dr. George T. Hahn, consultant in the Metal Science Group; George McClure, director of the Solid Mechanics Research Group; F. W. Boulger, chief of the Metal Working Research Division; Robert Eiber, research engineer in the Solid Mechanics Research Group; P. J. Rieppel, chief of the Metals Joining Research Division; and T. J. Atterbury, project leader of the Solid Mechanics Research Group.

Line Pipe

Research on line pipe, generally, has been to determine mechanical and fracture properties under operating conditions. During the first three years studies were made to determine the conditions that propagated cracks in pipe once they start. In later years the program has been concerned with the conditions under which cracks initiate.

Many factors may cause or contribute to pipe failure other than wall thickness, contrary to earlier beliefs. Temperature, backfill conditions, bends, and out-of-roundness are a few of the influences on the stress pattern.

During the past year experiments were run to define further some of the factors involved in initiation of cracks in defects, earlier research having determined that all field leaks and failures start at some kind of defect. Experiments involved pressure tests using 30-in. and 16-in. diam X-52 pipe in which defects were imposed artificially.

Investigated were three general types of defects: (1) stress concentrators consisting of V-notches, weld cracks, and gouges in round pipe; (2) plain dents, and (3) dents with a stress concentrator.

Results of the investigations revealed that:

1. Stress concentrators in round pipe fail at a net-section stress equal to the ultimate strength. Net-section stress is defined as the nominal stress calculated by using the thinnest portion of the pipe wall beneath the stress concentrator in the Barlow Formula. Temperature did not have an effect on this type of defect. The value of this information is that failure pressure can be fairly accurately estimated for stress concentrators when roundness of the pipe is not changed.

2. Plain dents up to 10% of the pipe diameter, in depth, are not serious defects. This is because the pipe has sufficient ductility to yield and accept the stresses without failure. An exception is in the case of dents near the longitudinal seam due to change in metallurgy near the weld. Another finding was that the higher the test pressure to which a plain dent is subjected, the less severe it will be upon repressuring . . . the dent is ironed out, so to speak.

As a result of this work, two areas are seen for the revision of Code B 31. One has to do with measuring the depth of the dent. The present method is to lay a straight edge across the dent and measure from that horizontal plane. But this doesn't take into account out-of-roundness of pipe. The suggested method is to take the minimum diameter in the dent and subtract it from the actual pipe diameter adjacent to the dent itself.

The other suggested revision to the Code is that allowable dent depth be based on a relationship with pipe diameter, percentagewise. The Code now requires that dents more than ¼-in. deep be removed from pipe intended to be operated at more than 50% of the specified minimum yield strength.

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The most severe type of defect is one having a stress concentrator in combination with a dent, and failures can be at comparatively low pressure, it has been learned. A defect of this kind is sensitive to temperature, failing at high stress levels at high temperatures and at lower stress levels when the temperature is reduced. However, it is possible to minimize the temperature effect by testing the defect to a high pressure level at high temperature.

Investigation of field leaks and failures are other phases of the research program. Types of defects that caused these failures were found to be: (1) dents and gouges (which were the major ones); (2) hard spot in the pipe wall (a metallurgical defect perhaps caused by quenching); (3) fatigue cracks in pipe wall (caused by a rivet head in a rail car rubbing the wall of the pipe); (4) corrosion in the longitudinal weld of an older bare line.

Most of these leaks or failures occurred during initial testing of the line, several after the line was in operation. The observation here was: Inspect well and test well after construction to remove defects from the line before it is placed in operation.

What of line pipe manufacture? Fundamentally, the research program has been to learn more about present material in use and determine the causes that trigger failures. Failures are few and line pipe for the most part has been of good quality, it was pointed out, but this does not preclude the desirability of learning the why of failures and the effects of metallurgical factors on the properties of pipe.

Higher strength steels with improved fracturing properties is one of the prime targets for the future. The properties of a steel depend on its composition. It is known that manganese imparts toughness and strength. Carbon increases strength but reduces the toughness. It appears, then, that the best composition is one that includes the least carbon and the highest manganese content within practicable limits. But that is not the entire answer.

Finer grains in steel also improve toughness and strength. So the method of rolling the sheet is important. Control of the temperature at which the steel is rolled is most important because it must be rolled at a reduced temperature to give a finer grain.

Actually, a fully deoxidized killed steel is best . . . it is stronger and tougher than any other . . . but it is also more expensive. The problem overall, then, is to obtain a higher strength steel, improve fracturing properties, and do so economically. The industry is now ready to put to use its findings in the direction of obtaining line pipe made of steels having what it considers better composition.

Thus far pipe tests have been made with relatively few grades of steel. Laboratory studies will now be made using various heats. It is felt that more information is needed on the effects of cold rolling, wall thickness, quenching, and tempering, among other things. Various alloying elements will be given thorough study. Notch strength is not as great as the industry would like for it to be, but this should be achieved as greater strengths are obtained.

Secondary Stresses

Secondary stresses are those occurring on a pipeline after it is buried but which are not the result of internal pressure. Among these stresses are those occasioned by branch connections, soil load, bending, out-of-roundness induced by external pressure, dents, etc. In this study operating companies performed their own experimental investigations and submitted the data for evaluation to Battelle Institute as a part of the AGA project. Tests were made following construction, after lines were tested, and while lines were in operation.

Some of the conclusions are:

1. Certain construction stresses are quite high.
2. Line testing relieves some of these stresses. For example, dents, which are straightened under pressure, as has been mentioned.
3. Those stresses remaining stay fairly constant.
4. High secondary stresses are not detrimental if stress raisers (concentrators) are not present.

Results of the secondary stress work will serve as a future guide to the pipeline designer, giving him greater knowledge of the factors for which he must design.

Girth Welding Practices

Steel composition, preheat and postheat, and proper welding electrodes were emphasized as principal factors in controlling underbead cracking in girth joints, repair welds, etc. Electrodes high in hydrogen cause most underbead cracks, it was pointed out, and low-hydrogen electrodes are sometimes unusable because of the difficulty of welding with them in all positions.

Cracks do not occur in the heat affected zone in low carbon steels . . . when the carbon equivalent is below 60 there will be little underbead cracking at girth joints. Welding at low temperature enhances the possibility of underbead cracks. Preheating in a range of 200 to 400 F before welding is suggested. And making the second pass immediately after the first pass while the metal is still hot will help to prevent such cracks. Still another means of preventing underbead cracks is inert gas shielding.

Branch Connection Reinforcements

The research project on branch connections has two phases: (1) design of branch connection reinforcements, and (2) determining the effects of cyclic loads on branch connections.

Data accumulated on stresses in reinforced and unreinforced branch connections will be the basis for recommended changes in Code B 31.8 on design of branch connections. Performance of several branch connection reinforcements designed using the proposed new rules is now being studied in the laboratory. Results will determine whether the proposed recommendations are sound and whether the stresses are approximately as predicted.

Certain preliminary determinations have been made: (1) that as the thickness of the branch connection approaches the thickness of the header the stress is less, and (2) reinforcement in the longitudinal direction doesn't need to be as long as is now the practice. Aim of the studies is to provide a guide to what areas need reinforcement the most.

Good alignment and proper fabrication were emphasized as the leading factors in preventing fatigue cracks in compressor station piping caused by cyclic loads. Greatest strains are found in suction headers. Research is continuing to provide a piping design that will minimize the amplitude of these dynamic stresses at these and other points.

Conclusion

American Gas Association will publish a full report on the research program discussed here. We have only attempted to present the highlights. The A.G.A. report will be in two parts. The first, a general discussion, will be issued possibly the latter part of June. The second part will be more technical and will be available at some later date.

It was stressed at the Dallas seminar that the pipeline research program definitely will be a continuing one. Answers have been found in some fields, but all answers are not known. Data obtained thus far can be used now in day-to-day operations, but many solutions are still in the future.

A proposal is under consideration to provide installations for full-scale tests, which would accelerate evaluations of new pipe compositions, welding methods, and other problems now under consideration, as well as still others that may come to the fore at future times. ★ ★ ★

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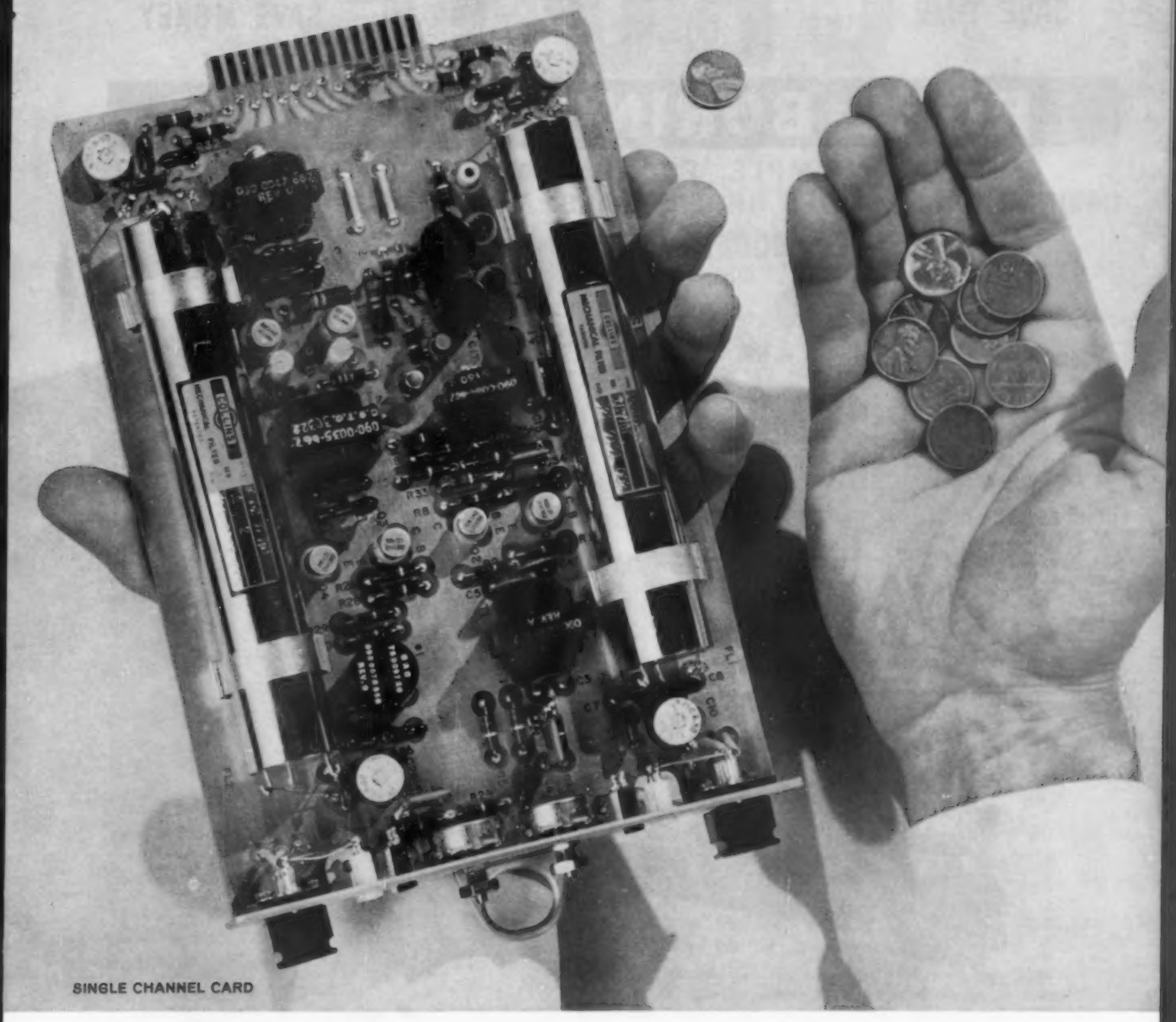

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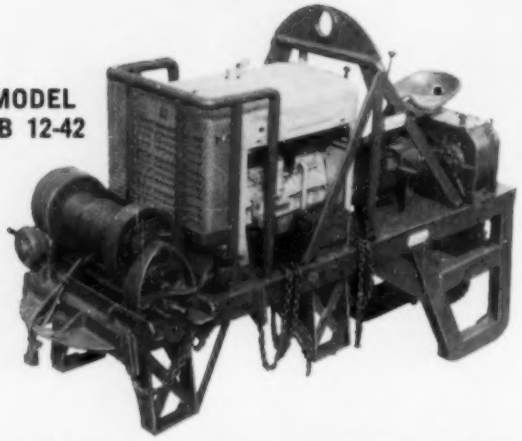

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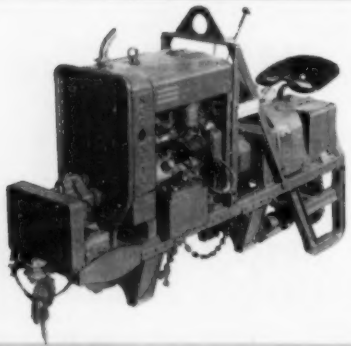

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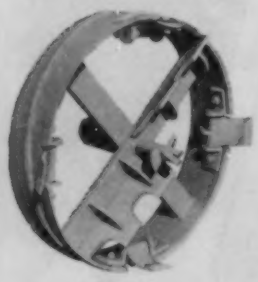

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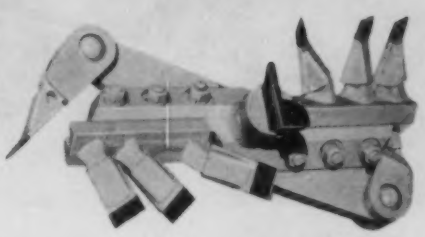

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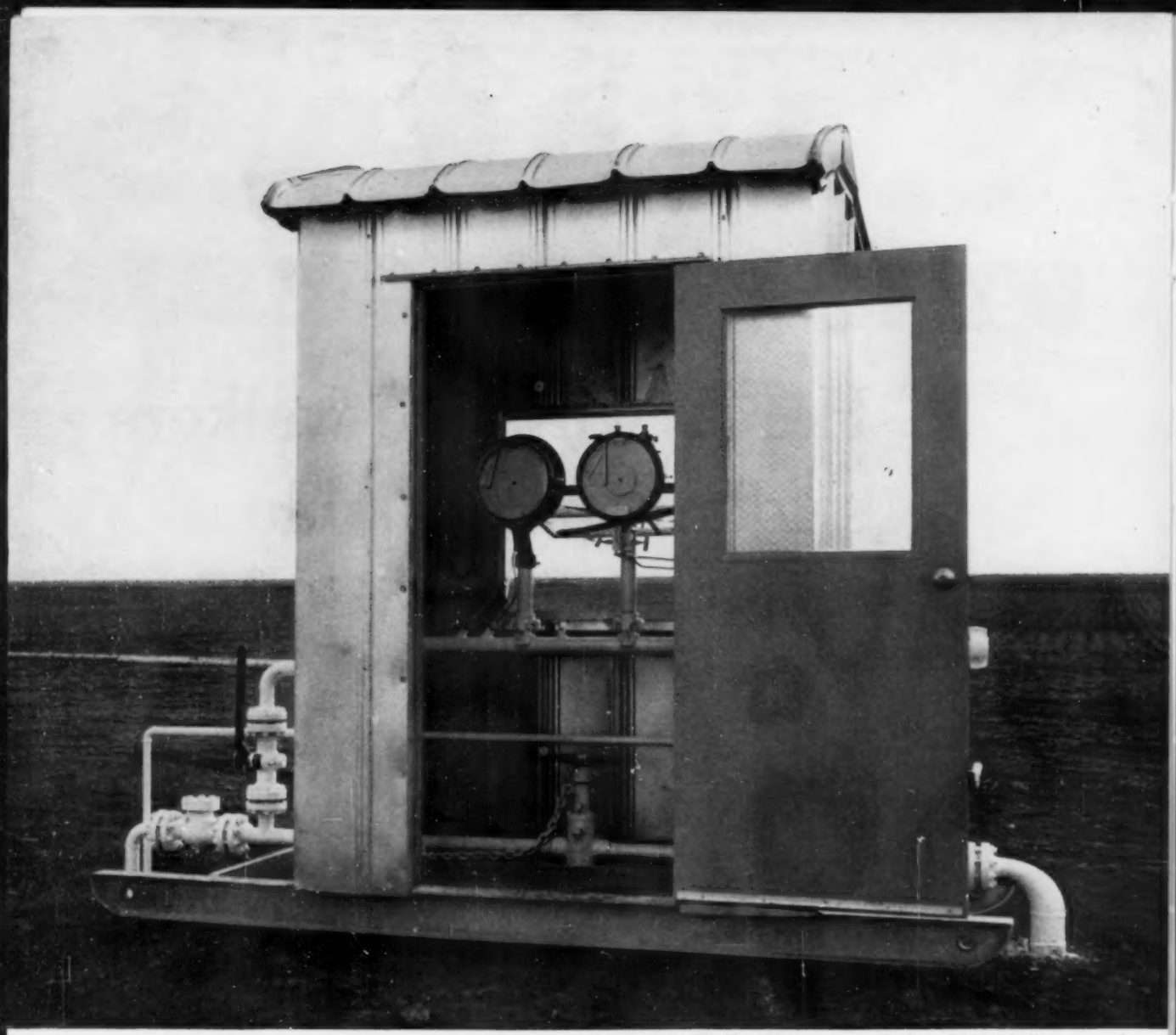

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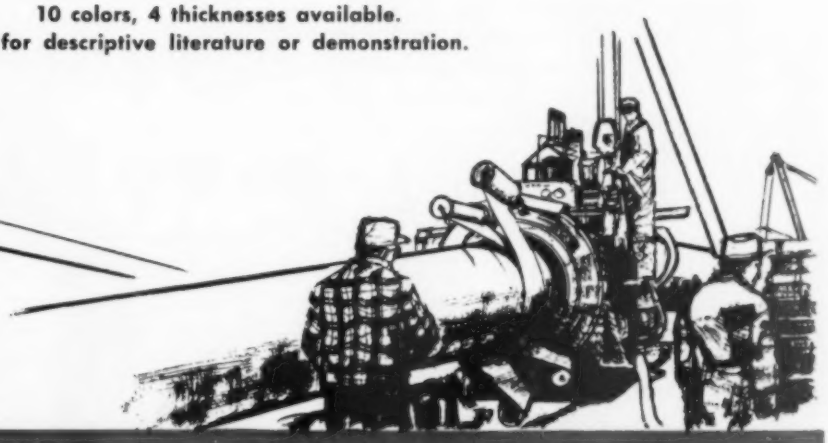

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382-Mile Expansion Wins Examiner's Okay

Three applications by Northern Natural Gas Company involving construction of 382 miles of pipelines and an additional 20,660 hp in compressor capacity has been approved in a Federal Power Commission examiner's decision.

The $37,500,000 construction will increase system sales capacity by 174,050,000 cu ft daily.

The decision includes authorization for Northern Natural to sell 75,000,000 cu ft of this increased capacity to Michigan Wisconsin Pipe Line Company and for the latter to build about 88 miles of pipeline and 3000 hp compressor capacity at a cost of $6,556,000.

170-Mile Expansion To Stimulate Anadarko

A pipeline project which will include 170 miles of construction and provide a market boost for North Anadarko Basin crude oil is planned by Sinclair Pipe Line Company.

Sinclair will purchase from Cameron Crude Oil Corporation the existing Wheat Belt pipelines in Harper County, Oklahoma, and Clark County, Kansas, plus gathering systems serving producers and a gas products plant in the Laverne-Stockholm-Buffalo areas of Harper County. The 170-mile pipeline to be constructed will link the existing facilities to Sinclair's main system at Shawnee, Oklahoma, about 40 miles east of Oklahoma City.

Total investment in the combined project is estimated at between $6,000,000 and $7,000,000. Initial volume of the new pipeline is estimated at 10,000 bbl daily.

Construction will begin immediately. Upon its completion, crude oil, condensate, and the gas plant products can then be moved to major refinery areas at Houston, Texas, and Wood River and Chicago, Illinois.

New Louisiana Gas Line

An 11-mile extension to serve Lafayette, Louisiana, with natural gas is one of the pipeline system additions planned by Louisiana Intrastate Gas Corporation in 1961.

Plans were revealed in the 1961 budget announced by the firm's parent, Central Louisiana Electric Company, Inc.

Industrial Line Approved

A measuring and regulating station and six miles of 8-in. pipeline to enable Kansas-Nebraska Natural Gas Company, Inc., to sell and deliver to a new fertilizer plant near Hastings, Nebraska, has received Federal Power Commission authorization.

At the time Kansas-Nebraska filed the $115,000 construction application, it was said that construction would begin August 1.

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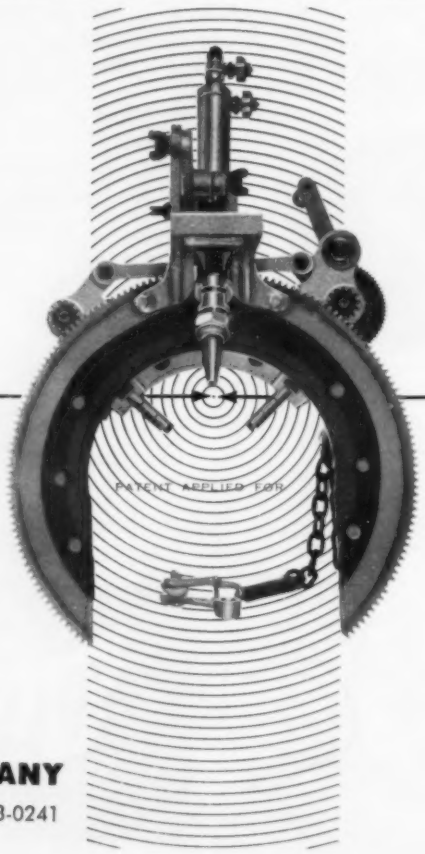

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Gas Liquids Line Proposed In West-Central Alberta

Royalite Oil Company, Ltd., has applied to the Alberta department of mines and minerals for permission to lay a short natural gas liquids pipeline to connect two gas processing plants with Calgary area refineries.

The 25-mile, 4-in. line, with initial capacity of 11,000 bbl per day, would run from the north end of the Jumping Pound gas field to a point on Royalite's wholly-owned Valley pipeline a few miles southwest of Calgary.

The proposed line would draw gas liquids, mainly condensate, from the Jumping Pound gas processing plant, already in operation, and from a new plant being built and scheduled to go on stream by November 1 in the Wildcat Hills gas field adjoining Jumping Pound on the northwest.

Both plant operators have firm delivery contracts with Alberta and Southern Gas Company, Ltd., for export of gas to California.

15-Mile, 36-In. Loop Okayed

The Federal Power Commission has authorized Transcontinental Gas Pipe Line Corporation to construct and operate a pipeline loop to bypass a hydroelectric project being built by Duke Power Company on the Catawba River in North Carolina.

Transco will build about 15 miles of 36-in. main line loop, add weights to existing loop segments that will be flooded, and relocate a water pumping station, at an estimated cost of $2,860,000. Duke will reimburse Transco with an amount estimated at $1,371,777.

Open to U. S. bidders is the laying of a 180-mile, $20,000,000 gas pipeline in Germany southward from Mannheim to Kehl via Karlsruhe and eastward from Karlsruhe to Ulm. U.S. firms can obtain preliminary information from Director Juergen Stech, Technische Werke Stuttgart, Stuttgart, West Germany, a member of the managing board of Gasversorgung, Sueddeutschland, sponsor of the project.

Seeks Short Crude Line In East Central Alberta

A Canadian independent marketing firm specializing in crude oil purchases from distress or marginal areas is seeking permission to lay a 32-mile, 3-in. pipeline from the Hamilton Lake field in east central Alberta to a connection with the Interprovincial pipeline.

The line proposed to the Alberta Department of Mines and Minerals by Gibson Associated Oils, Ltd., would tie in at the north end to an existing gathering system serving the Bellshill Lake and Thompson Lake fields. At the south end, it would connect with an existing short line between the Hamilton Lake field and the rail point of Throne. Both lines are owned by Gibson.

Westcoast Plans Outlet For New Alberta Field

Westcoast Transmission Company, Ltd., has revealed plans to connect its northeastern British Columbia gas gathering system to a newly developed gas field in northwestern Alberta.

The firm proposes a 40-mile, small-diameter line from the Worsley gas field, where six wells have been completed, to its existing terminus in the Boundary Lake gas field. The line would also take gas from the Floral field at the half-way point.

Gas from both Worsley and Floral is sweet and requires only desiccant treatment to remove a small liquid content. However, a small processing plant will be built at Boundary Lake if the pipeline plans are completed. This plant would consist of one amine treating unit. Boundary Lake gas cannot be taken into the Westcoast system at present because of sulfur content.

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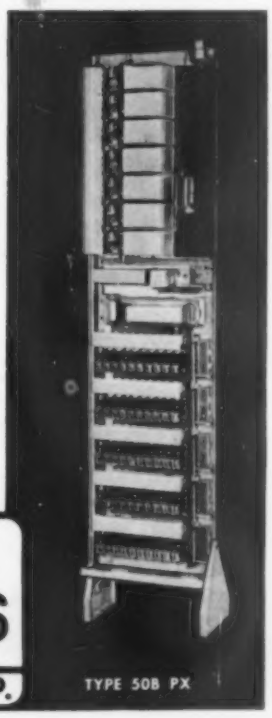

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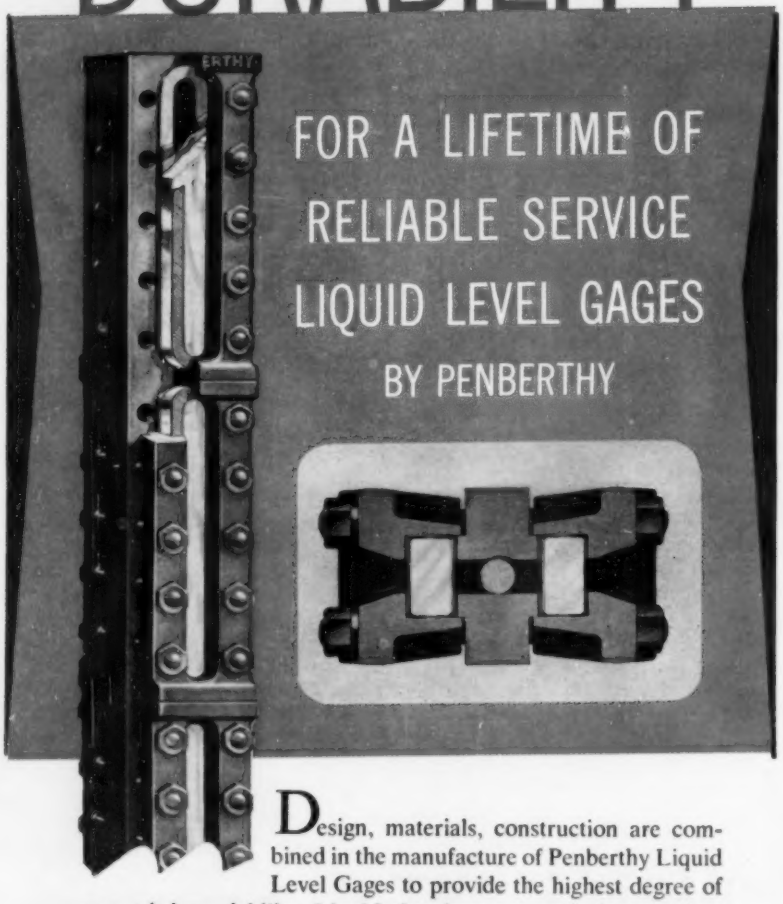

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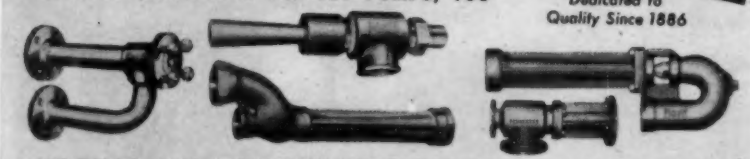

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FPC FILINGS

El Paso Natural Gas Co., El Paso, Texas, CP 61-248, filed March 20.

Construction: In Washington, 61.3 miles of 10¾ in. OD (Bremerton Lateral) from near Olympia to near Gorst, including crossings of the Deschutes and Black rivers, for sale and delivery to Cascade Natural Gas Corporation.

Cost: $2,296,000, which includes: $2,047,420 for materials and labor; $15,000 for river crossings; $21,000 for metering stations; and $208,000 in overheads and contingencies.

Montana-Dakota Utilities Co., Minneapolis, Minnesota, CP 61-234, filed March 7, 1961.

Construction: 106-mile, 12¾ in. OD gas transmission line from near Minot to near Bismarck, North Dakota, with measurement and regulating station near terminus; plus 2⅜ in. OD branch lines and city gate stations to serve Minot Radar Base, and Max, Garrison, Turtle Lake, Underwood, Washburn, and Wilton, North Dakota.

Cost: $4,288,380 total, of which $3,400,000 is for the 106-mile transmission line, as follows: $2,100,000 for bare line pipe; $3000 for 500 ft of 18-in. OD casing pipe; $3000 for 600 ft of 16-in. OD casing pipe; $125,310 for coating materials; $63,000 for valve setting; $12,800 for miscellaneous materials; $95,400 for right-of-way; $723,700 for contract labor; $79,900 for labor and supervision; $160,290 for contingencies; and $33,600 for interest.

Transwestern Pipeline Co., Houston, Texas, CP 61-243, filed March 15.

Construction: 41 miles of 8⅝-in. between the Bluitt plant, Roosevelt County, New Mexico, and the 24-in. Panhandle lateral in New Mexico; and 7 miles of 4½-in. between the plant and gas wells.

Cost: 904,760 total. For the 41-mile line: $417,720 for pipe; $34,650 for coating; $5900 for trap and launcher; $6400 for cased crossings; $21,000 for miscellaneous; $132,990 for installation; and $52,480 for right-of-way. For the 7-mile line: $34,450 for pipe; $3300 for coating; $2980 for trap and launcher; $1600 for cased crossings; $13,030 for miscellaneous; $18,580 for installation; and $8960 for right-of-way. The Bluitt plant measuring station, $13,900, which includes $9880 for material and $4020 for labor. The North Bluitt measuring station, $10,350, which includes $6340 for materials and $4010 for labor.

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

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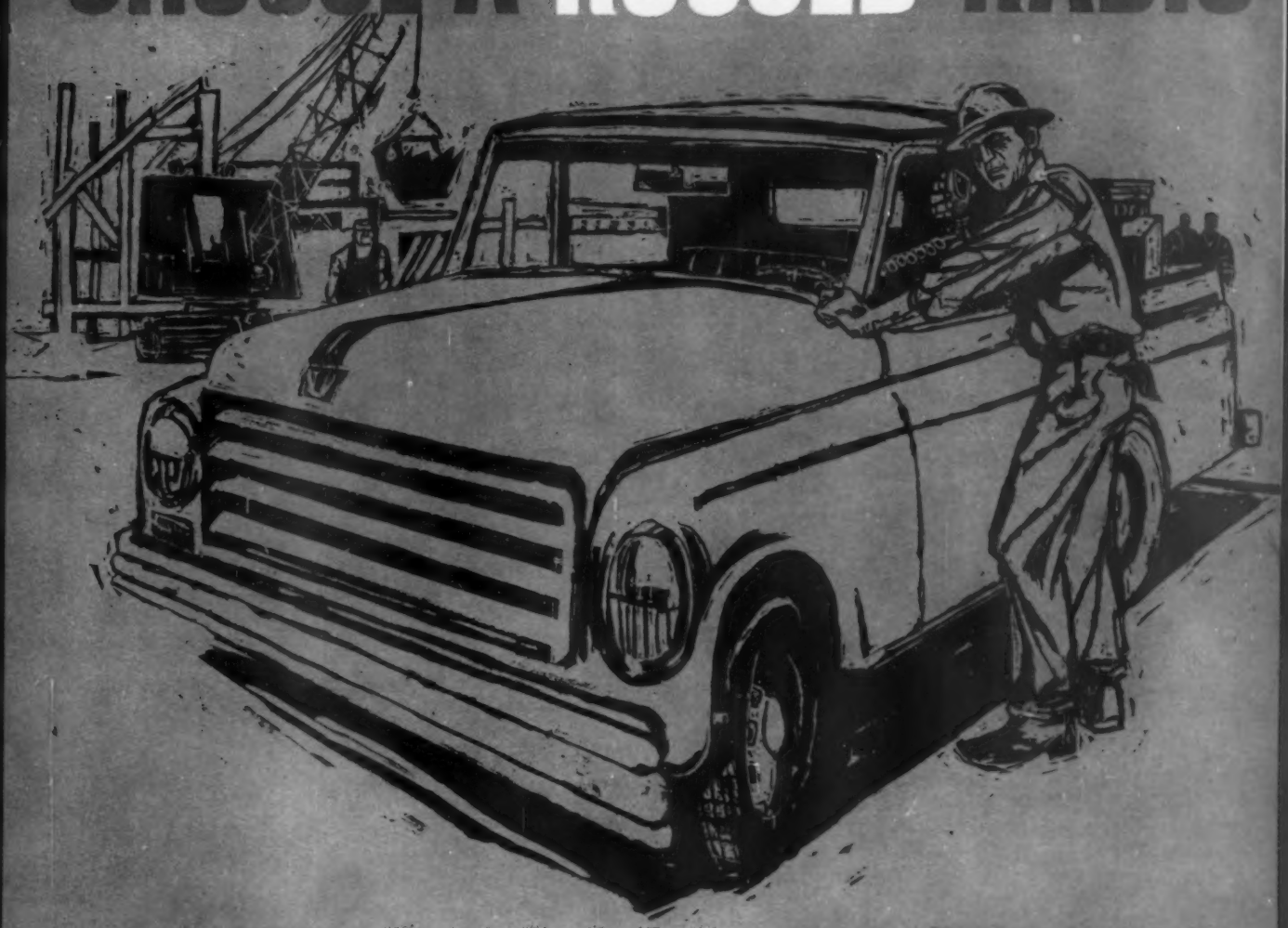

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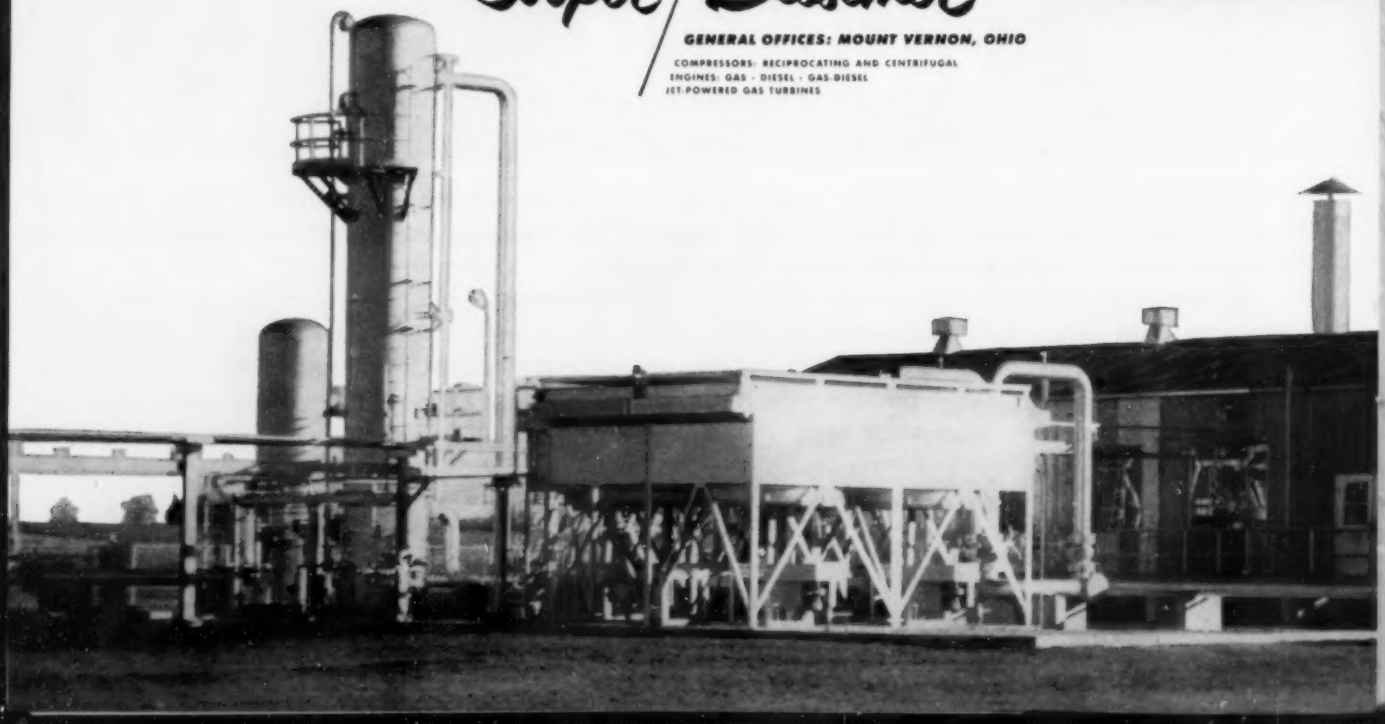
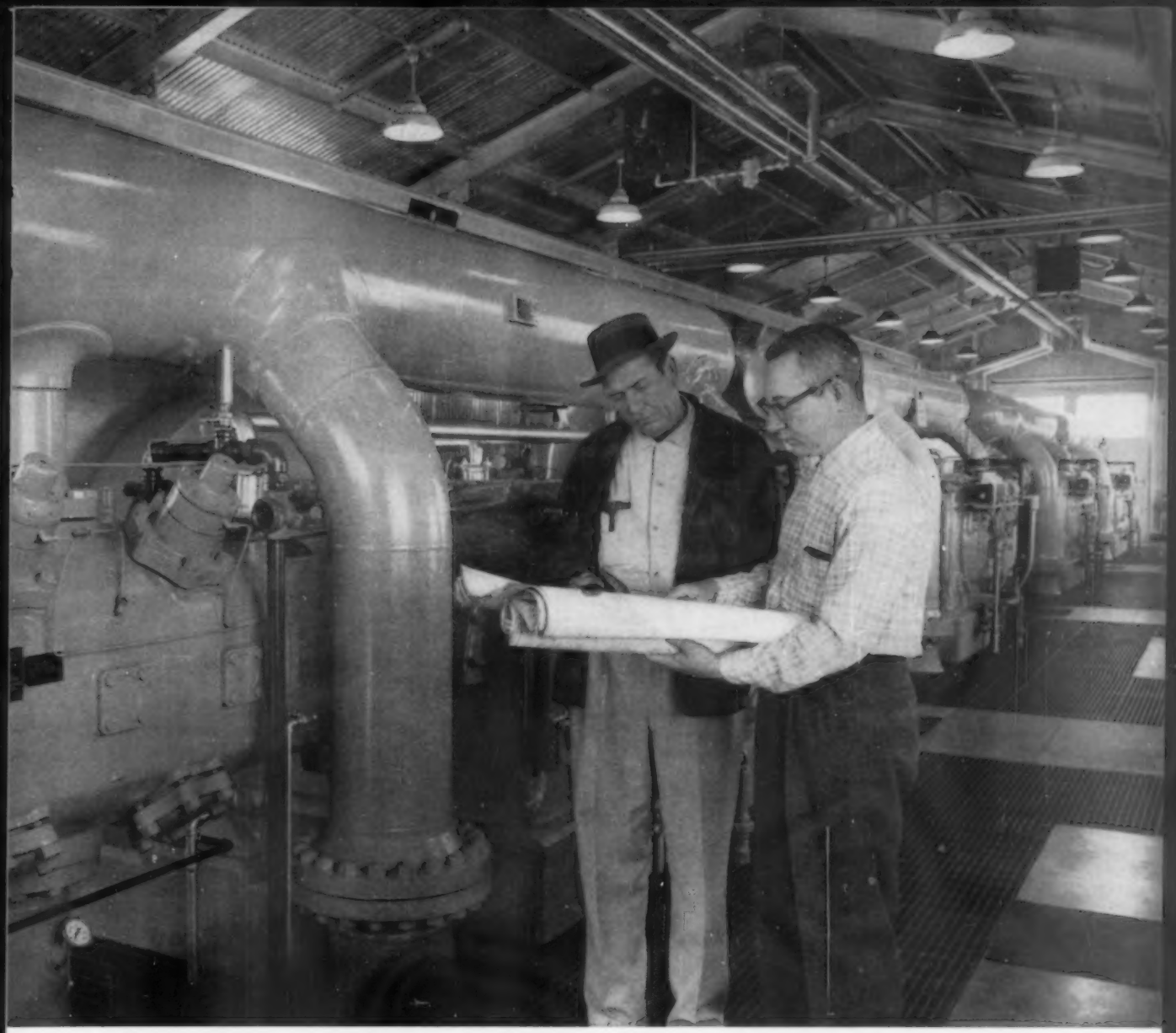
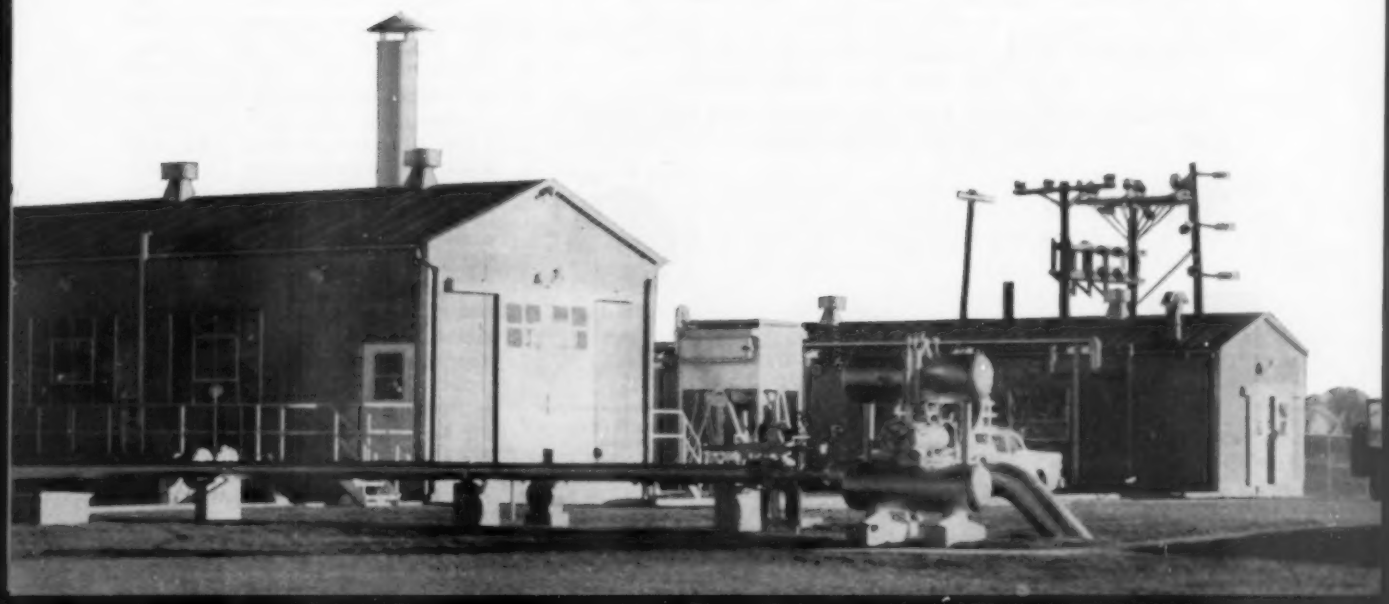




W. M. May, Freeburg Station Superintendent, and K. W. Robertson, Gas Engineer of Illinois Power, discuss recent expansion of Freeburg Station. Its four 700 hp Cooper-Bessemer FM Compressors pump 36,000 mcf/day at 65 psi suction and 260 psi discharge.



FPC FILINGS

Michigan-Wisconsin Pipe Line Co., Detroit, Michigan, CP 61-252, filed March 24, 1961.

Construction: Lateral and gathering facilities under a budget-type application (exact facilities and location not determined).

Cost: $3,000,000 total, with individual projects limited to $500,000.

Texas Gas Transmission Corp., Owensboro, Kentucky, CP 61-247, filed March 20, 1961.

Construction: 56.50 miles of 30-in. loops in Louisiana, Arkansas, Mississippi, Tennessee, and Kentucky; 20.75 miles of 26-in. loops in Kentucky, Indiana, and Ohio; two 24-in. crossings under the Mississippi River near Greenville, Mississippi; and addition of two 2000-hp compressor units at the Hardinsburg, Kentucky, compressor station. Construction — to increase firm service to Texas Eastern Transmission Corporation from 235,000 to 285,000 Mcf — is to be completed in time for operation by November 1, 1962.

Cost: $12,913,000 (including contingencies and supervision). $6,031,400 for the 56.50 miles of 30-in. includes: $314,310 for survey and right-of-way; $3,873,862 for materials; $1,724,994 for installation; and $118, 234 for engineering and supervision. $2,109,700 for the 20.75 miles of 26-in. includes: $139,336 for survey and right-of-way; $1,036,928 for materials; $892,051 for installation; and $41,385 for engineering and supervision. $2,042,400 for the Mississippi River crossings includes $20,000 for survey and right-of-way; $466,100 for materials; $1,506,500 for installation; and $49,800 for engineering. $1,529,550 for the horsepower additions includes: $943,035 for materials; $502,715 for installation; and $83,800 for engineering and supervision.

CP 61-254, filed March 27, 1961.

Construction: Measuring and regulating stations and other facilities under budget-type application.

Cost: $100,000 total, with individual projects not to exceed $15,000.

Trunkline Gas Co., Houston, Texas, CP 61-241, filed March 15, 1961.

Construction: Additional 3000-hp at each of eight existing main line stations, from station 48 (Longville, Louisiana) to station 112 (Johnsonville, Illinois); 76.8 miles of 26-in. OD pipeline to station 48 from junction of gathering lines from Bayou Sale field in St. Mary's Parish, Louisiana, and Block 14 field off Vermilion Parish (Cow Island); 24.2 miles of 18-in. OD looping existing 16-in. gathering line from shore to Cow Island; and measuring facilities for sales proposed to Mississippi River Transmission Corporation; Illinois Power Company; Colfax, Louisiana; Byhalia, Mississippi; Somerville and Newbern, Tennessee; Hickman and Clinton, Kentucky; Vienna, McLeansboro, and Wayne City, Illinois; and Michigan Gas Utilities Company.

Cost: $18,000,000 total. $7,517,000 for the 26-in. line includes: $4,286,300 for pipe; $176,600 for coating; $109,300 for valve settings; $157,200 for miscellaneous; $1,988,900 for contractor, equipment, and labor; $258,200 for engineering and $540,500 for right-of-way. $2,310,000 for the 18-in. line includes: $880,200 for pipe; $77,500 for right-of-way and damages; $20,200 for valve settings; $41,000 for crossover setting; $63,200 for coatings; $28,200 for miscellaneous; $1,094,200 for contract, labor, and equipment; and $105,500 for engineering. Horsepower additions will total $6,944,000. Measuring facilities at Bourbon, Illinois, $115,000. Communications facilities, $32,000.

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● **O. R. Burden Construction Corp., Box 5216, Tulsa, Oklahoma.**

Alamo Gas Supply Co. — 291 miles of 14 through 24-in. in southwest Texas to supply gas to San Antonio, Texas.

● **R. H. Fulton & Co., Box 1526, Lubbock, Texas.**

Continental Pipe Line Co.—550 miles of 2, 3, 4, 6, and 8-in. in Montana and Wyoming.

Northern Natural Gas Co. — 428 miles of 2 through 10-in. in Iowa.

● **Groninger & King, Inc., Box 1381, Pampa, Texas.**

Northern Natural Gas Co.—15 miles of 4 through 10-in. gathering lines in Spearman, Texas, Beaver, Oklahoma, and Ashland, Kansas, areas. W. G. Puckett is supervising at Spearman and Frank Kelp at Beaver.

● **Hall Construction Co., 1105 N. Carlton, Liberal, Kansas.**

Panhandle Eastern Pipe Line Co. — a 330-mile, 4 through 12-in. gathering system in western Kansas. Supervising are Mike Bell and M. E. Banning.

● **Harbert Construction Corp., Drawer 75, Birmingham, Alabama.**

Northern Natural Gas Co. — 138 miles of 2 through 8-in. lateral lines in Minnesota. Field office: Pine Island. Superintendent: Jay Cundiff.

● **Latex Constuction Co. of Ga., Box 11668, Atlanta 5, Georgia.**

Plantation Pipe Line Co. — reconditioning 65 miles of 10-in. loops between Winder, Georgia, and Greensboro, North Carolina. Field office: Statham, Georgia. Superintendent: Glenn Matlock.

● **J. P. Neill and Company, Meadows Building, Dallas, Texas.**

Pacific Gas Transmission Company — 468 miles of 36-in. from California-Oregon boundary to Rosalia, Washington, as joint venture with Western Pipeline, Inc., Austin, Texas. Hermiston, Oregon, is field office now for a 153-mile, 36-in. segment from Hermiston to Rosalia, Washington. Jack Hays is superintendent, and Glen Goyne is office manager.

● **Oklahoma Pipe Line Constructors, 6612 Harry Hines Blvd., Dallas, Texas.**

Portland Pipe Line Corp. — taking up, reconditioning, and relaying a 50-mile, 18-in. crude line in Maine and Vermont. South Paris, Maine, is location of field office. Superintendents are Leman Creech and Guy Craft.

● **Panama, Inc., 1801 Tennessee Bldg., Houston 2, Texas.**

Trunkline Gas Co. — 21 miles of 30-in. north from Byhalia, Mississippi, including two river crossings.

● **H. C. Price Co., Price Tower, Bartlesville, Oklahoma.**

Pacific Gas & Electric Co. — 291 miles of 36-in. to the Oregon border from the San Francisco Bay area. Superintendent: R. L. Ezell. Office Manager: Bob Walker at McArthur, California.

Pacific Gas Transmission Company—146 miles of 36-in. from Rosalia, Washington, to the Idaho-British Columbia border. Superintendent: G. A. Reutzel. Office manager: E. Dickson at Veradale, Washington.

Texas Eastern Transmission Corp. — 26 miles of 30 through 36-in. in New Jersey from near Lambertville to New Brunswick, with Elwood Roth supervising. Nick Beffer is office manager at Flemington.

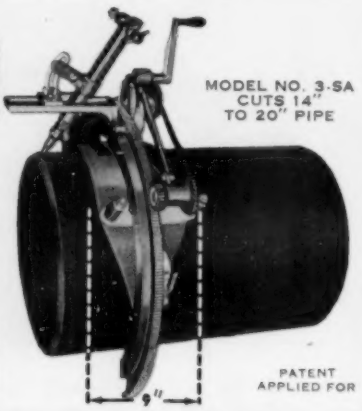
● **Price-Poole of Canada, Ltd., Box 969, Cranbrook, B. C., Canada.**

Alberta Natural Gas Company — 107 miles of 36-in. from Crowsnest Pass to the Idaho boundary at Kingsgate-Eastport. Joint venture of H. C. Price Company of Canada, Ltd., Calgary, and Poole Construction Company, Ltd., Edmonton. C. E. Shivel is superintendent, and L. D. Burden is office manager at Cranbrook, B. C.

● **R. E. Reutzel Co., Inc., Box 727, Fremont, Nebraska.**

Northern Natural Gas Co. — 116 miles of 2 through 8-in. in South Dakota. Harold Holmes is superintendent and R. E. Whitworth is office manager.

NEW!



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● **River Construction Corp., Box 9127, Ft. Worth 7, Texas.**

Pacific Gas Transmission Co.— 36-in. single-line crossings of the Kootenai and Pend Oreille rivers near Bonners Ferry and Sandpoint, Idaho, respectively, sites of headquarters. H. H. Mehail is superintendent.

Service Pipe Line Co. — 60 miles of 12-in. loops on the LaPlata, Missouri — Wood River, Illinois, trunk line. Headquarters: LaPlata and Bowling Green, Missouri. Superintendent: T. M. Tatom.

● **Shamrock Construction Co., Box 1177, Lansing, Michigan.**

Northern Natural Gas Co. — 130 miles of 2 through 8-in. laterals in Iowa.

● **Sheehan Pipe Line Construction Co., 514 National Bank of Tulsa Bldg., Tulsa, Oklahoma.**

Transwestern Pipeline Co. — has underway an additional 100 miles on the 4, 6, 8, 10, and 12-in. gathering system in Oklahoma, Texas, and New Mexico.

● **Stanley-Bledsoe Corp., 612 Daniel Bldg., Tulsa 3, Oklahoma.**

Pacific Gas Transmission Co.—double-jointing and yard-treating 466 miles of 36-in. pipe in three schedules in Klamath, Jefferson, Umatilla, and Gilliam counties, Oregon, and Walla Walla and Whitman counties, Washington. Superintendent: W. D. Smith, Jr.

● **Western Pipeline, Inc., 311 East 11th Street, Austin, Texas.**

Pacific Gas Transmission Company — 468 miles of 36-in. from California-Oregon boundary to Rosalia, Washington, as joint venture with J. P. Neill and Company, Inc., Dallas, Texas. J. C. Oliver is project manager. Johnnie Wells is superintendent on a 150-mile segment between Malin and Bend, Oregon; and Ervin Simpson is superintendent on 150 miles between Bend and north of Ione, Oregon.

● **J. O. (Red) Willett Pipe Line Stringing Corp., Box 2836, Monroe, Louisiana.**

United Gas Pipe Line Co. — unloading 51 miles of pipe at Tioga, Louisiana; 60 miles at Loreauville, Louisiana; and 59 miles at Columbia, Louisiana.

● **H. B. Zachry Co., Box 10188, San Antonio 21, Texas.**

United Gas Pipe Line Co. — a 22-mile, 24-in. between Harris and Ft. Bend counties, Texas.

● **Williams Bros. Co., National Bank of Tulsa Bldg., Tulsa, Oklahoma.**

National Iranian Oil Co. — a 516 mile, 8-in. petroleum products line in Iran from Rey, near Tehran, northeast to Meshed.

Bataafse Petroleum Maatschappij, N.V. —a 157-mile, 20-in. pipeline in Indonesia. Field office: Balikpapan. Superintendent: J. Childress.

Niederoesterreichische Gasvertriebs, AG (NIOGAS) — 47 miles of 8 through 10-in. in Austria. Headquarters: Herzogenberg. Superintendent: W. Tierney.

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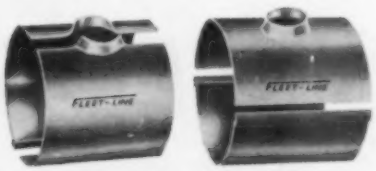

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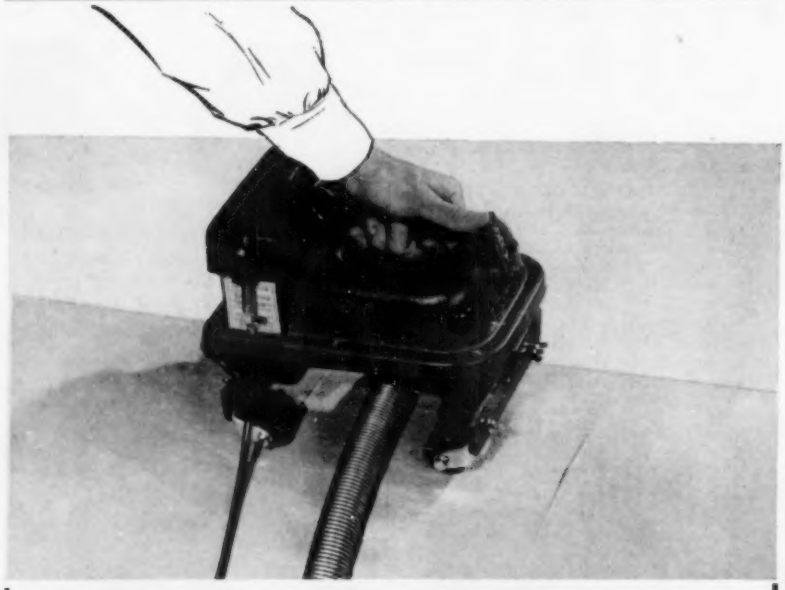
An improved version of the Mark V flow transducer, in the form of a probe, features applicability to unlimited line sizes and flow rates and one-man installation without special tools through a low-cost flanged fitting fabricated in the pipeline. It meters any fluid that can be safely contained in stainless steel. The relative cost of the Mark V is reduced as line size increases. The transducer can be remotely located and the signal telemetered many miles; systems can be provided to permit indicating, recording, controlling and totalizing flows. It can be provided for pressures to 5000 psi and temperatures to 600 F. *Ramapo Instrument Co., Inc.*

Circle number (81) on reply card.

Extra Compact Pumps

Suction and packing arrangement for handling fluids beyond the range of power pumps now on the market, without pressurized suction, is claimed for the line of Barry V45 quadruplex plunger pumps now available in several sizes on three frame sizes with six models. With compact, lightweight V-type construction, the line is designed for direct drive to crankshaft, gear drive integral with pump, or V-belt drive. Suction valves are placed so that fluid never stops nor changes direction while being pumped, and non-adjustable packing with rigid metal body holds the lip in place so the packing cannot flow. *W. R. Barry Pump Co.*

Circle number (82) on reply card.



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It's New

Handy Hand Calculator

Offering to contractors, estimators, field engineers, and surveyors "on-the-spot" mathematical answers is a new calculator. It is cylindrically-shaped, easily held and operated in one hand, noiseless, rust and corrosion-proof, and requires no external power supply. It has an 11-digit keyboard, 8-digit indicator dial, and 15-digit (corresponding to 999 trillion) answer dial. A continuous tens transfer and reversing lever permits short-cut techniques in basic operations of multiplication, division, addition, subtraction, and multiple operations involving cubes, roots, percentiles, and trigonometric functions. *The Curta Co.*

Circle number (83) on reply card.

Large 6-Wheel Scraper

With payload capacity of 125,000 lb, struck capacity of 40 cu yd, S.A.E. rating (heaped at 1:1 slope) of 52 yd, and 432-hp GM 12-cylinder diesel engine, the SS-40 scraper is capable of long, high-speed hauls at speeds up to 34 mph. It has full power shift of four forward and two reverse speed ranges, hydraulic scraper operations, and completely new double ram actuated "push-out, roll-out" ejector which provides extra force at the beginning to overcome inertia with maximum speed at the end of the stroke and a final snap action for fast, clean shedding of the load—even sticky materials. *Euclid Div., General Motors Corp.*

Circle number (84) on reply card.

Lubricator Safety Feature

A new device for use on McCord model "55" force feed lubricators acts as a safety feature giving warning that entrained air can stop oil feeding of the lubricator. The No. A-32156 Safe Level Sight Feed features: quick, easy priming without disconnecting oil line; field installation on all existing model "55" force feed lubricators; servicing of the lubricator feed without disturbing the sight feed glass; and improved sealing by metal to metal contact. It is now installed on all currently manufactured model "55's" *McCord Corp.*

Circle number (85) on reply card.

Simple Sampling

A new liquid sampler for any pipeline regardless of pressure can be operated either manually by turning a handle a quarter turn, or automatically by a motor and timing device. This drains a sample trapped in a drain plug into a sample container. There is nothing to drain, clean, or bleed before taking a sample; it is taken at line pressure and stored in the container at atmospheric pressure. Every sample contains a full cross-section of fluid in the line, is taken without restricting the flow of liquid, and is always of equal volume permitting computing a correct composite sample. *ARCCO Instrument Co., Inc.*

Circle number (86) on reply card.

Pipeline Equipment

Portable Impact Compactor

An improved self-propelled, one-man earth compactor now makes it possible to tamp narrow ditches as little as 4 in. in width and up to 40 in. in depth. This improved Rapak has a one-shot lubrication system built into the head of the machine as an integral part; new sleeved, 4-cycle engine and heavy-duty centrifugal clutch; delivers 450 heavy ram blows per min; and is designed to compact all types of granular as well as cohesive soils. *Racine Hydraulics & Machinery, Inc.*

Circle number (87) on reply card.

Sphere, Pig Detector

The Mark IV Sphere Here is a stainless steel, completely pressure-balanced unit for any gas or liquid pipeline. Designed to detect with equal response from either direction, it can be installed at launching or receiving traps, or at any desired intermediate point, in any position on pipe, simply by drilling a 1¾-in. hole and welding on pre-scarfed base. Welding saddle or pad may be used, if desired. The Sphere Here is available with any or all of four accessories: micro switch, visual indicator, five-digit counter, pneumatic pilot valve. It is especially well-suited for use on high speed, displacement type meter-provers. *F. H. Maloney Co.*

Circle number (88) on reply card.

New Line-Mounted Meter

Now available is a new 7000-cfh rotary positive displacement meter for gas measurement at pressures to 125 psi. Connections are flanged to ASA C.I. standards for easy mounting in a 3-in. pipe. No special supports are required for mounting the meter either vertically or horizontally. The volume counter of this line-mounted Rootsmeter is protected inside the case with heavy sight-glass for easy reading. The meter also can be provided for standard instrumentation. A bull's-eye oil-level gage makes checking easy. The only maintenance required is an occasional replenishment of the oil. *Roots-Connersville Blower, Div. of Dresser Industries, Inc.*

Circle number (89) on reply card.

New Type Line-Up Clamp

Now available is an internal line-up clamp that exerts high pressures (up to 4000 lb) hydraulically on a full 360-deg inside circumference of both ends of the pipe to be welded. This eliminates spot pressure method of rounding pipe ends and resulting high-lows. The hydraulic pump can be electrically operated from welding machine or separate generator on a tractor. The operator controls the clamp through simple pushbutton controls. Easily traversing 90-deg tube turns, the new line-up clamp automatically locks into place with a solenoid operated brake. Designed primarily for yard welding but easily converted for operation on main lines, it is available in 10 through 36-in. and up models. *Work-Remco Co.*

Circle number (90) on reply card.

Cushion Action Push Dozers

The No. 8C and No. 9C pushloading dozers for Cat D8H and D9E series tractors permit push tractor approach and contact with scrapers at relative speeds up to 3 mph and are equally effective for smoothing the cut, haul road repairs, and other normal dozing work. A single lift cylinder for hydraulic controls gives operators improved forward vision. More complete cushioning is accomplished by lengthening the travel distance before "bottoming" of the four rubber springs, each of which is composed of 11 separate discs made of a new and softer rubber compound. *Caterpillar Tractor Co.*

Circle number (91) on reply card.

KERMAC Outerwrap KERMAC

resists damage during lowering-in and backfilling

Kermac — the tough, durable glass Outerwrap — provides thoroughly reliable protection against the damaging effects of soil stress. Reducing the threat of costly holidays that often result from these operations is important to the economy of any pipe line, and Kermac Outerwrap is designed specifically for that purpose.

Kermac's bonded, fibrous glass mat is reinforced by strong glass yarns, and is saturated with special bitumens. These outstanding features assure a constant and adequate safeguard for your protective enamels during lowering-in and backfilling.

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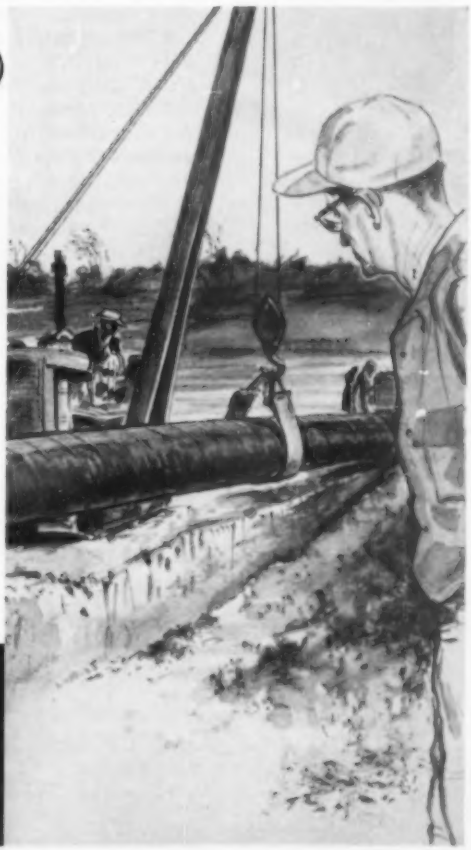

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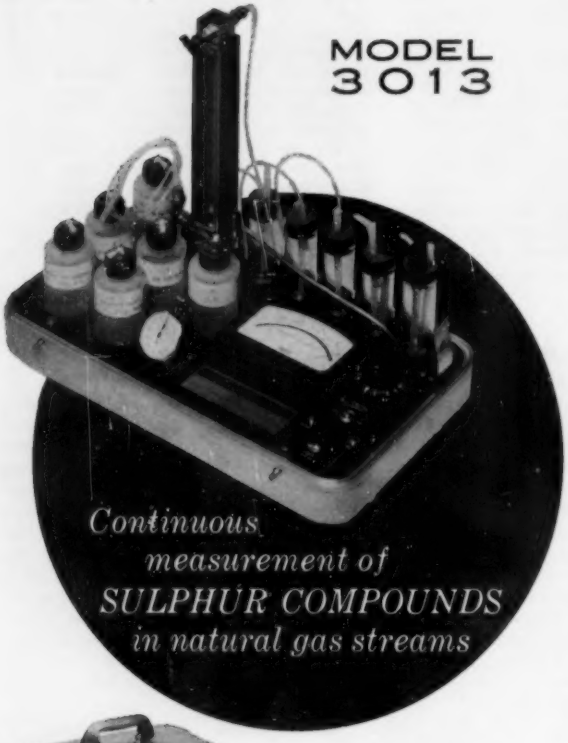
MODEL 3013



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Protects Hot Surfaces

"Sili-Kool" is a new low-cost silicon base aluminum protective paint for hot metal surfaces. One coat of this new combination of silicone and atomized silver aluminum, because of its bonding feature, is said to protect for more than a year stacks, boilers, hot air pipes, diesel and gasoline manifolds, mufflers, and vapor or steam pipes generating temperatures up to 1600 F. No priming or undercoating are necessary. *C. H. Dragert Co., Inc.*

Circle number (92) on reply card.

Rock Loader

Greater digging force and larger bucket are two important features of the new Eimco 24 RockerShovel. Called a new and greatly improved model replacing the Eimco 21 RockerShovel, it also features patented replaceable rail design and arrangement of bumper springs in arms, enclosed in cylinders for increased machine stability and longer spring life without sacrifice of machine length or bucket discharge distance. *The Eimco Corp.*

Circle number (93) on reply card.

420 HP Wheel Tractor-Scrapers

Two new wheel tractor-scrapers feature an exclusive torque divider power shift transmission which automatically selects proper drive in each of three speed ranges and fits engine output to exactly meet load and material conditions. The 4-wheel 630A has a top speed of 41 mph and the 631A, 31 mph. Both are powered by a new 4-valve-in-head diesel engine with maximum rating of 420 hp and flywheel rating of 335 hp; and feature specially developed 28 ply 29.5 by 35 tires. Lowbowl scrapers have struck capacity of 21 cu yd and heaped capacity of 28 cu yd, with refinements permitting corner voids to be filled without staying excessively long in the cut. For extra-large production capabilities under special job conditions, a new unit — the 630A-482C tractor-scraper combination—will be available. *Caterpillar Tractor Co.*

Circle number (94) on reply card.

New Multi-Purpose Pumps

New 1½-in. and 2-in. self-priming centrifugal pumps, weighing as little as 54 lb with convenient carrying handle, have been introduced for a number of uses — from fire protection to sump pumping and boosting pressure for equipment cleaning. There are gasoline, electric, and universal drive models in the two series—engineered for capacities to 5600 gal per hr. This is the first time, according to the manufacturer, that a close-coupled electric drive method has been applied to such a compact-design pump. It can be hooked up to any power source. *Barnes Manufacturing Co.*

Circle number (95) on reply card.

Has "Built-In Operator"

Now available for licensed manufacture is a new line-operated high pressure pipeline valve. Manufacture in 500, 1500, and 3000 psi capacities is anticipated for the patented valve which is full flow, non-lubricated and will handle fluids, slurries, and gases. It may be operated by line pressure alone or by normal pneumatic, hydraulic, and electric systems. It is undergoing field tests near Houston, Texas. *KeXplore, Inc.*

Circle number (96) on reply card.

For Control Functions

A new completely solid-state adjustable set point control relay with micro-micro watt input levels of d-c current or voltage and power up to 30-w in output offers laboratory performance under severe environmental conditions. The A-82 provides stable resolution and adjustability of set point of ± 1 microamp over the entire standard range of 0-100 d-c microamp. Complementary outputs of 1 amp at line voltage for over set point and under set point are available for alarms, lights, power relays, or other control functions. *Daystrom, Inc.*

Circle number (97) on reply card.

For Microwave Continuity

A new, specially-designed Kato motor-generator features unique flywheel arrangement which provides momentum, in case of failure of normal electric power, to keep fluctuation to a minimum until standby power is cut into the line. Brushless-type generator with direct connected separate exciter is rated at 5 kw, 6.25 kva, 0.8 factor, 120 v a-c, 1 phase, 50 cps. Motor is 10 hp, 208/416 v a-c, 1500 rpm, 50 cycles, 3-phase, wound rotor induction type. *Kato Engineering Co.*

Circle number (98) on reply card.

It's New | Pipeline Literature

Dial-O-Graph, which automates recording instrument operation, is the subject of an illustrated bulletin. This chart changer makes possible any recording cycle, the synchronization of any number of recorders to change at exactly the same time, and the group loading of as many as 50 charts at a time. Only 1/10th second elapses during chart change, and completed charts are stored in chronological order in a metal catcher mounted below the instrument. Can run for weeks at a time unattended. *Mullins Mfg. Co., Inc.*

Circle number (99) on reply card.

Portable Diaphragm Pumps . . . in 2, 3, and 4-in. sizes for heavy-duty service such as oil tank sludging and pipeline construction . . . are described in literature giving specifications for those with swing-type valves and those with ball-type valves. *Rice Pump and Machine Co.*

Circle number (100) on reply card.

Quick-Opening Hinged Closures for blanking off pipeline ends and tank or vessel openings have undergone design changes described in a new bulletin. Illustrations show one-weld installation, easy maintenance, one-man operation, and built-in safety features. *Tube Turns Div., Chemetron Corp.*

Circle number (101) on reply card.

New Plugging Pig Method for plugging and evacuating pipelines and hydrostatic testing of existing or new lines is explained in a new booklet. Step-by-step cross-section illustrations show positive alignment and locking of pig, and other pages are devoted to tandem plugging for repairs or additions and to hydrostatic testing. *Pipeline Plugging Pig, Inc.*

Circle number (102) on reply card.

Tape-To-Tape Converters that are completely solid-state, either uni- or bi-directional, and capable of "rearranging" information during conversion are featured in a new 4-pager. *Daystrom, Inc.*

Circle number (103) on reply card.

Liquid Level Gage . . . electrically-powered and calibrated to 1/16 in. . . . is featured in a new 4-pager. How the new Varec high-pressure "Dynamatic" operates highlights the bulletin. *The Vapor Recovery Systems Co.*

Circle number (104) on reply card.

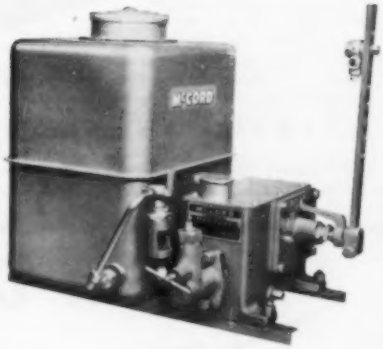
Percussion Bits . . . including bottoming, shoulder, push-on, and throw-away in a complete range of threads and tapers . . . for fast, clean blast holes on tough jobs . . . are described in an illustrated catalog. *Vascoloy-Ramet Corp.*

Circle number (105) on reply card.

SPECIALLY DESIGNED

for injecting chemicals into crude oil lines

McCORD TYPE "C" Chemical Pump



Finest pump ever developed for oil field use . . . unexcelled, also, for accurate dependable metering of acids, oils, other liquids. Five sizes, ¼" to ⅝" diameter plungers . . . capacities from .452 cc to 2.85 cc per full stroke, against pressures up to 2,000 lbs. Exclusive drip sight feed . . . external stroke adjustment and test screw to check delivery . . . all working parts enclosed and protected. Available with 5 drives: electric motor, rotary pulley, direct connected, ratchet, gas motor . . . the latter enabling you to use waste gas as your power source. Consult your McCord field engineer.

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EMERGENCY PIPE CLAMP

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Speediest application — slotted lug permits the single plated bolt to slide instantly into place.

A companion to the old reliable Emergency Pipe Clamp that has served industry for a half century, the JUNIOR, a single bolt clamp, is 2⅞" wide. Undersells most band-type clamps.

Made of malleable iron, ruggedly proportioned, with full-length hinge along one side. Formed to exact pipe size—no bending. The recessed pressure-equalizing gasket, entire width of clamp, is cemented in. A lasting installation. 2" pipe size—$1.80; 2½"—$2.20; 3"—$2.30. Write for new circular on the Junior.

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Warning Lights, Flares, Barricades . . . for truck users, construction spreads (marking road and highway crossings) . . . are described in a new catalog. Many applications of this complete line of safety devices are pointed out. *Electronic Specialties Co.*

Circle number (106) on reply card.

For Fast Digging, Handling, Dumping . .. a group of all-welded clamshell buckets are described in a 4-pager. It outlines—with ratings, dimensions, weights—general purpose digging, rehandling, and extra light rehandling buckets, as well as rock tongs in 10 and 20-ton capacities. *M. P. McCaffrey, Inc.*

Circle number (107) on reply card.

Two Part Teeth . . . adapters to fit any shovel dipper, dragline bucket, backhoe, or scarifier . . . and straight, wedge, flared, pick, or rock type points . . . are featured in an illustrated bulletin highlighted by diagrams of locking device. *Apex Equipment Co., Inc.*

Circle number (108) on reply card.

Want To Know what Bucyrus blades are available for what machines? A brochure has been released listing the cutting edges and the lines for which they are available. *Bucyrus Blades Inc.*

Circle number (109) on reply card.

"Make More Dollars Move" shows how two popular-sized crawler crane-excavators perform on pipeline work. Hoe, shovel, clam, dragline, and crane front ends are illustrated. *Koehring Div.*

Circle number (110) on reply card.

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PIPELINE VENTS AND MARKERS

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GUESSWORK
out of BURIED HOLIDAYS

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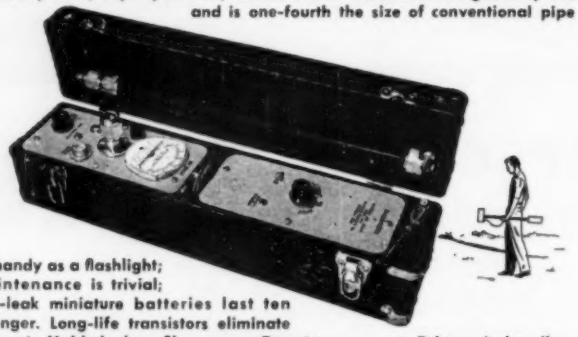
The MINIATURIZED-PRECISION
WILKINSON Line Locator Model W-3

This radically new, super-powered, transistorized instrument weighs only four pounds and is one-fourth the size of conventional pipe locators.



It is as handy as a flashlight; the maintenance is trivial; the non-leak miniature batteries last ten times longer. Long-life transistors eliminate replacement. Molded glass fibre cases. Transistor ear set. Telescopic handle. Etched circuitry. Contained in carrying case.

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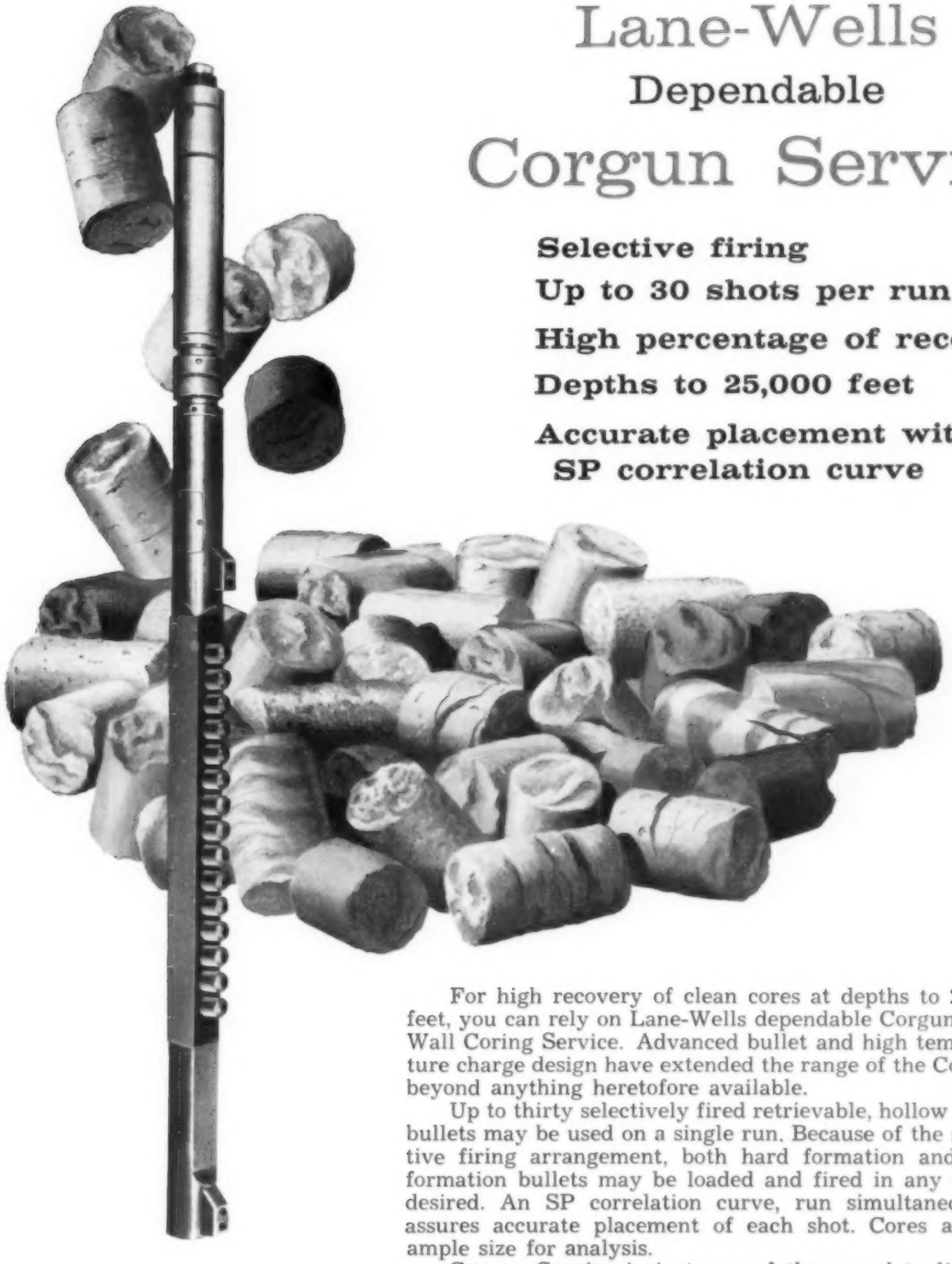
Up to 30 shots per run
High percentage of recovery
Depths to 25,000 feet
Accurate placement with SP correlation curve



For high recovery of clean cores at depths to 25,000 feet, you can rely on Lane-Wells dependable Corgun Side Wall Coring Service. Advanced bullet and high temperature charge design have extended the range of the Corgun beyond anything heretofore available.

Up to thirty selectively fired retrievable, hollow point bullets may be used on a single run. Because of the selective firing arrangement, both hard formation and soft formation bullets may be loaded and fired in any order desired. An SP correlation curve, run simultaneously, assures accurate placement of each shot. Cores are of ample size for analysis.

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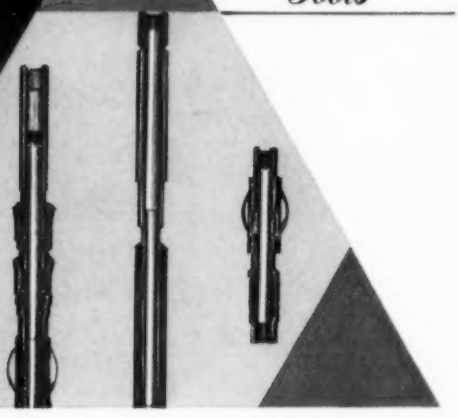
Tools



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